

MANAGEMENT OF INSECT PESTS OF POTATO WITH SOME NOVEL INSECTICIDES

Thesis

Submitted to the



G. B. Pant University of Agriculture & Technology
Pantnagar- 263145, Uttarakhand, India

By

Anil Rana

B. Sc. (Horticulture)

*IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF*

**Master of Science in Agriculture
(Entomology)**

August, 2019

ACKNOWLEDGEMENT

We dream, we desire and we strive to achieve our dreams; and finally it is god's grace and our perseverance that pays and then we achieve what we dream. First of all, I bow my head towards the god who has guided me all way and for the many blessing that has been bestowed upon me.

Thank you, Almighty for always being with me and giving me this opportunity to acknowledge all those who gave me long lasting memories in past two years during my stay at Pantnagar.

*The precious gift of learning is a debt that is difficult to pay. Only gratitude can be felt. Indeed, the words at my command are inadequate in form or in spirit to express my heartfelt, deep sense of unbound gratitude and indebtedness to **Dr. R.M. Srivastava (Professor, Entomology)** chairman of my Advisory Committee for laying out the guidelines of research work and training to my mind to think systematically and logically. I have real appreciation and regard for him for his keen interest, scholarly and judicious guidance, advice, constructive criticism, and encouragement during the course of investigation.*

*I deem it to be my privilege to express my veneration for the eminent member of my Advisory Committee **Dr. R.P. Srivastava (Professor, Entomology)** and **Dr. M.S. Khan (Professor, Entomology)** who contribute meaningfully. I extend my sincere thanks to all the teachers of Entomology Department for providing support wherever needed and necessary research facilities for conducting the present study. And my sincere thanks to **Dr. Pramod Mall (Head, Entomology)**, Dean Ag, Dean PGS, and University Library for their kind cooperation during the course of my study*

I would also like to give thanks to my seniors specially Chenesh sir, Gaurav sir, Jai hind Sharma sir, S.N. Tiwari sir, Dina mam, Salni mam and Sneha mam, and my batchmates Vinay, Pardeep, Kamal, Rajneesh, Himanshu, Bhujendra, Mrityunjoy, Mayank, Abhishek, Diksha, Priyanka, Neha, Vidhi and loving juniors specially Rupam, Ajay dhyan, for their continuous help, support, thoughtfulness and for being perennial source of inspiration throughout my degree programme.

I find lacunae of words to express my feelings but from the core of my heart I would like to express my thanks to my friends Digvijay, Rajendar, Arvind, Niket, Manoj, Subham, Rahul, Pankaj, Navneet, Saurabh, Monika, Susmita, Sita, Pari, for their humorous company, affection, inspiration, and all time availability for help during my stay at Pantnagar.

With my heart full of enthusiasm, I place this study at the feet of my beloved parents Sri Jayveer Singh Rana and Smt. Ram Dei who to me are incarnations of God in this world and are the inspiration behind every achievement of my life. I cannot ever pay for their continuous sacrifices and pains that they have taken to make me withstand every difficulty of my life with patience and perseverance. These are only their blessings and love that helped me to conduct and compile this work without any obstacle.

I could not find appropriate words in the lexicon to accentuate my profound regards to my uncle Mr. Soban Rana and Aunty Mrs. Parkshi Rana; My sister Shweta Rana My brothers Naresh, Nitesh, Manish, Trilock Rana and all my family members for their boundless generosity, everlasting inspiration and abundant love, without which, I might not have been able to pursue my consistence.

My sincere thanks to Vijay bhaiya and other worker for their valuable cooperation during the course of field trail. I would also like to thank all who could not find a separate name but have helped me directly or indirectly.

I am deeply indebted to Pharul sir, Santosh sir, Amit sir, Jungi Yadav ji and staff members of Department of Entomology, for their help in conducting the experiment and helping me throughout my degree programme.

Pantnagar
August, 2019


Anil Rana
03-08-2019
(Anil Rana)
Author

CERTIFICATE

This is to certify that the thesis entitled “**MANAGEMENT OF INSECT PESTS OF POTATO WITH SOME NOVEL INSECTICIDES**” submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture**, with major in **Entomology** of the College of Post-Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Anil Rana, Id. No. 52538**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Pantnagar
August, 2019


(R. M. Srivastava)
Chairman
Advisory committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Mr. Anil Rana, Id. No. 52538**, a candidate for the degree of **Master of Science in Agriculture**, with major in **Entomology**, agree that the thesis entitled **“MANAGEMENT OF INSECT PESTS OF POTATO WITH SOME NOVEL INSECTICIDES”** may be submitted in partial fulfillment of the requirements for the degree.



(R. M. Srivastava)
Chairman
Advisory Committee



(R. P. Srivastava)
Member



(M. S. Khan)
Member

CONTENTS

S. No.	CHAPTER	Page No.
1	INTRODUCTION	
2.	REVIEW OF LITERATURE	
3.	MATERIALS AND METHODS	
4.	RESULTS AND DISCUSSION	
5.	SUMMARY AND CONCLUSION	
	LITERATURE CITED	
	APPENDICES	
	VITA	
	ABSTRACT	

LIST OF TABLES

Table No.	Details of Table	Page No.
4.1	Biodiversity of insect and mite fauna in potato ecosystem.	
4.2	Mean population of <i>Myzus persicae</i> in relation to weather parameters in potato (2018-19)- Pantnagar, Uttarakhand	
4.3	Mean population of <i>Bemisia tabaci</i> in relation to weather parameters in potato (2018-19)- Pantnagar, Uttarakhand	
4.4	Mean population of <i>Empoasca devastans</i> in relation to weather parameters in potato (2018-19)- Pantnagar, Uttarakhand	
4.5	Mean population of <i>Thrips palmi</i> in relation to weather parameters in potato (2018-19)- Pantnagar, Uttarakhand	
4.6	Mean population of natural enemies and its correlation with weather parameters in potato (2018-19)- Pantnagar, Uttarakhand	
4.7	Correlation coefficients - sucking pests <i>vis-vis</i> coccinellid, spider and staphylinid beetle in potato (2018-19)- Pantnagar, Uttarakhand	
4.8	Efficacy of flonicamid and imidacloprid foliar spray against whitefly (2018-19)	
4.9	Efficacy of flonicamid and imidacloprid foliar spray against aphid (2018-19)	
4.10	Efficacy of flonicamid and imidacloprid foliar spray green hopper (2018-19)	
4.11	Efficacy of flonicamid and imidacloprid foliar spray against thrips (2018-19)	
4.12	Effect of flonicamid and imidacloprid foliar spray against coccinellids (2018-19)	
4.13	Effect of flonicamid and imidacloprid foliar spray against spiders (2018-19)	
4.14	Effect of flonicamid and imidacloprid on yield of potato after foliar application (2018-19)	
4.15	Efficacy of different insecticidal foliar spray and seed treatment against white fly (2018-19)	
4.16	Efficacy of different insecticides foliar spray and seed treatment against aphid (2018-19)	
4.17	Efficacy of different insecticides foliar spray and seed treatment against green hopper (2018-19)	
4.18	Efficacy of different insecticides foliar spray and seed treatment against thrips (2018-19)	
4.19	Effect of different insecticidal foliar spray and seed treatment on yield of potato (2018-19)	

LIST OF FIGURES

Figure No.	Details of figure	Page No.
4.1	Mean population of <i>Myzus persicae</i> in relation to weather parameters in potato (2018-19)- Pantnagar, Uttarakhand	
4.2	Mean population of <i>Bemisia tabaci</i> in relation to weather parameters in potato (2018-19)- Pantnagar, Uttarakhand	
4.3	Mean population of <i>Empoasca devastans</i> in relation to weather parameters in potato (2018-19)- Pantnagar, Uttarakhand	
4.4	Mean population of <i>Thrips palmi</i> in relation to weather parameters in potato (2018-19)- Pantnagar, Uttarakhand	
4.5	Mean population of natural enemies and its correlation with weather parameters in potato (2018-19)	
4.6	Regression of population dynamics of natural enemies with sucking insect pest of potato during <i>rabi</i> season 2018-19	
4.7	Efficacy of flonicamid and imidacloprid foliar spray against whitefly (2018-19)	
4.8	Efficacy of flonicamid and imidacloprid foliar spray against aphid (2018-19)	
4.9	Efficacy of flonicamid and imidacloprid foliar spray green hopper (2018-19)	
4.10	Efficacy of flonicamid and imidacloprid foliar spray against thrips (2018-19)	
4.11	Effect of flonicamid and imidacloprid on yield of potato after foliar application (2018-19)	
4.12	Efficacy of different insecticidal foliar spray and seed treatment against white fly (2018-19)	
4.13	Efficacy of different insecticides foliar spray and seed treatment against aphid (2018-19)	
4.14	Efficacy of different insecticides foliar spray and seed treatment against green hopper (2018-19)	
4.15	Efficacy of different insecticides foliar spray and seed treatment against thrips (2018-19)	
4.16	Effect of different insecticidal foliar spray and seed treatment on yield of potato (2018-19)	

LIST OF PLATES

Plates No.	Details of Plates	Page No.
1	Sowing of potato, virus infection on potato plants, insecticide spray on potato crop, harvesting of potato	
2	A view of Experimental layout	
3	Beneficial insects associated with potato crop during crop season 2018-19	
4	Major and minor insect pests of potato crop	
5	Different species of ladybird beetles recorded on sucking pests of potato.	

LIST OF ABBREVIATIONS AND SYMBOLS

%	:	Percent
CD	:	Critical Difference
cm	:	Centimeter
d.f	:	Degree of freedom
<i>et al.</i>	:	Etali (Co-workers)
FS	:	Foliar spray
g	:	Gram
ha	:	Hectare
Ha ⁻¹	:	Per hectare
Hr.	:	Hour
Kg	:	Kilogram
Km	:	Kilometer
kmph	:	Kilometer per hour
lit	:	Litre
lits	:	Litres
m	:	Metre
MSE	:	Error mean squares
NS	:	Non-Significant
PTC	:	Pre-treatment count
RBD	:	Randomized Block Design
ROC	:	Reduction over control
SEm	:	Standard Error of Mean
SL	:	Soluble liquid
SS	:	Second spray
ST	:	Seed treatment
<i>viz.,</i>	:	Videlicet (namely)
WG	:	Water dispersible granule
WP	:	Wettable powder



Introduction



Potato, (*Solanum tuberosum* L.) (Family: Solanaceae) is one of the important vegetable crops produced across the nation and in numerous parts of the globe. It is grown in about 150 countries throughout the world and more than a billion people worldwide eat potato. About 388,191 MT of potato are produced in the world over an area of about 19,302,600.00 hectares (**FAOSTAT, 2017**). Potato is known as the king of vegetables and is among the five key crops cultivated by the farmers (**Sose, 2005**).

Potato tubers are very nutritious, enriched with minerals including calcium, potassium, Vitamin A and C, proteins, carbohydrates, and phosphorus. Moreover, it has significant amount of phenol compounds coupled with vitamin C as the potential amount of antioxidants (**Brown, 2005**) that inactivates reactive oxygen, reduces the oxidative damage, improves the immune system and reduces the risk of cancer, cardiovascular diseases, diabetes, aging, and cataract (**Kaur et al., 2004**).

The screening of literature revealed that several potatoes species are grown in over 150 countries across the globe and over a billion people consume them globally. The top ten global producing nations include Russia, China, USA, India, Germany, Ukraine, Belgium, Poland, France, and the Netherlands that contribute together about 70% of the overall production (**Anonymous, 2011**). India ranks 4th in terms of area and 3rd in terms of production of potato producing around 51310.00 MT from an area of 214200.0 hectares (**NHB, 2018**). Important potato producing states of India are Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, Punjab, Assam, Chhattisgarh, Uttarakhand and Odisha where Uttar Pradesh is the largest producer of potato (**MAFW, 2019**).

Potato crop in Uttarakhand contributes about 10 percent of the total country's output about 2500.90 hectares under cultivation. The production of potato during the year 2018 is 363.97 MT, productivity is about 22.09 T/ha (**SHM, 2018**). In Uttarakhand region, there are only certain key pests that must be specifically targeted for control. In seed production, the pests of greatest concern are usually the aphid vectors of potato viral diseases, especially *Myzus persicae*.

Potato is a *rabi* season crop which needs a low temperature, low humidity, less windy and bright sunny days. It does perform well under well-distributed rains or moist weather condition to high temperatures. Moreover, humidity and rains are not conducive to potato crop as often suffered from insects, nematodes and disease attacks. It is estimated that about 65% of the potato harvest is consumed by humans, 15% is processed and used as fodder, 12.5 % is retained for seed, and 7.5% is wasted due to spoilage (**Horton and Sawyer, 1985**).

Reported an actual loss of 39% due to insect pests in potato worldwide, and without crop protection about 71% of attainable potato production may be lost to pests (**Dehne, 2004**).

A number of sucking pests heavily attack this crop *viz.*, aphids (*Myzus persicae* Sulzer), thrips (*Thrips tabaci* Lindeman), jassids (*Amrasca biguttula biguttula* Ishida) and whiteflies (*Bemisia tabaci* Genn), spider mites *Tetranychus evansi* and *T. urticae*, (Tetranychidae) Plants nutrients are sucked by all the pests of potato which directly damage the plants resulting in twisting and curling of tender parts and general devitalization causing loss heavily (**Misra, 1995**). Thrips (*Thrips palmi* Karney) are the slender and small sucking insect which are less than 1 mm with fringed wings attach on the apical portion of foliage. They lacerate the epidermal layer and gulp the soring cell sap. They bring in *tospo* virus only at the nymph stage but they hold and transmit throughout life (**Butani and Jatwani, 1984**). Whiteflies (*Bemisia tabaci*) and aphids (*Myzus persicae*, *Aphis gossypii*) are tiny, small insects found on the lower surface of the leaves which gulp the cell sap from the succulent leaves and also excrete honeydew-like substance which delays normal physiological processes in the potato plants (**Metcalf and Flint, 1978**). Aphids are also responsible for transferring potato viruses M, A and Y, leafroll virus, apical leaf curl virus, and potato acute mosaic virus (**Chandel et al. 2007**) while thrips are responsible for transferring potato stem necrosis virus (**Jones, 2005**). Jassids (*Amrasca biguttula biguttula*) is one of the sucking insects that carries hopper burn in potato (**Lamp et al. 2004**).

These sucking pests of potatoes are responsible for heavy reduction in quality as well as yield of potatoes. Many reports indicated that mites suck the sap usually from the lower surface of leaves producing small white specks, which gradually dry and drop off. The decreased vitality and leaf drop adversely affects the plant growth, flowering,

and fruiting. In severe infestation, tetranychid mites web profusely and may form a thick sheath of webbing that covers the entire plant (**Grandjean, 1948 and Jeppson *et al.*, 1975**).

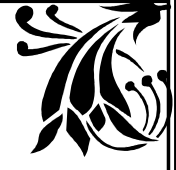
The chemicals in insect pest management play a vital role in controlling the pests so that different types of insecticides are repeatedly sprayed with high doses for controlling the population of above pests in potato which has resulted into resistance of pests to insecticides and 3 pest resurgence. Nowadays emphasis is being given on low-risk insecticides that are active at low field dosages having controlled action span and least non-target effect. Neonicotinoid insecticides are the fastest growing class of insecticides imported to the market since the launch of pyrethroids (**Nauen and Bretschneider, 2002**). Seven different neonicotinoid compounds are commercially available worldwide (**Jeschke *et al.*, 2011**). These are imidacloprid and thiacloprid (developed by Bayer Crop Science), thiamethoxam (Syngenta), acetamiprid (Nippon Soda), clothianidin (Bayer Crop Science and Sumitomo), nitenpyram (Sumitomo), and dinotefuran (Mitsui Chemicals). Among these imidacloprid is a systemic insecticide and it is the biggest selling insecticide worldwide with a market share above 600 million Euro per year (**Jemec *et al.*, 2007**). Key benefits of using systemic insecticides include the provision of continuous plant protection through most of the growing season without any need for repeated applications over contact insecticides. In addition, they are not susceptible to the UV light degradation or “wash off” during watering (**Herbert *et al.*, 2008**). The mode of action of neonicotinoid insecticides includes their agonistically action on the insect nicotinic acetylcholine receptors (nAChR). These are especially active on hemipteran pest species such as plant hoppers, whiteflies, and aphids (**Nauen *et al.*, 2012**).

Imidacloprid is highly effective against sucking insects such as leafhoppers, aphids, thrips and mealybugs, and very efficient against whitefly. It is also useful against some species of biting insects (**Elbert *et al.*, 1991**). Thiamethoxam, a neonicotinoid insecticide, has been widely accepted for the use in various crops, including vegetables, owing to its high efficacy against various chewing and sucking insect pests (**Karmakar *et al.*, 2009**). Flonicamid, a pyridine carboxamide compound, is a novel systemic insecticide with selective activity against hemipterous pests, such as aphids and whiteflies, and thysanopterous pests. Flonicamid is very active against

aphids, regardless of differences in species, stages and morphs. This compound inhibited the feeding behavior of aphids within 0.5 h of treatment without noticeable poisoning symptoms such as convulsion, and this antifeeding activity was not recoverable until death (**Morita *et al.*, 2007**).

Further, to develop economically feasible management strategy and to reduce unwarranted pesticide load in the environment, knowledge on safer pesticides is also very much essential. In view of the above facts, the present investigations are undertaken with the following objectives:

1. To study seasonal incidence of various insect pests and mite in potato crop in *Tarai* region of Uttarakhand.
2. Comparison of imidacloprid and flonicamid against insect pests of potato.
3. Bioefficacy of some novel insecticides as foliar spray and seed treatment against insect pests of potato.



*Review
of
Literature*



Potato (*Solanum tuberosum* Linn.) is an important Non-cereal crop and infested by a number of insect-pests of these sucking pests are the most important as they cause considerable losses. The references relevant to topic “*Management of insect pests of potato with some novel insecticides*” have been summarized.

2.1 To study seasonal incidence of various insect pests and mite in potato crop in Tarai region.

Several workers have reported the seasonal incidence of various sucking pests in potato crop.

Nag (2016) observed that the sucking pest like whitefly, aphid, thrips, leafhopper is the major insect pest of potato crop in Chhattisgarh plain region. The activity of all these insect pests commenced from second week of December on potato variety, Kufri lauvkar causing damage at various stages of the crop. The activity of leafhopper peaked during the third week of January recording 4.52 nymphs and adults per plant with seasonal mean of 2.57 per plant. The density of whitefly reached its peak population of 4.16 and 3.60 per plant during 3rd weeks of December and January with seasonal mean of 2.76 per plant. The aphids recorded its peak activity of 13.00 per plant during last week of January with a seasonal mean of 5.53 aphids per plant. It has been reported that imidacloprid 17.8 SL (150ml/ha) at 15 days interval was most effective against aphid, whiteflies, and thrips and thiamethoxam 25 WG (100g/ha) at 15 days interval was most effective against leafhopper.

2.1.1 Seasonal incidence of aphid, *Myzus persicae* (Sulz.) (Hemiptera: Aphididae) in potato crop.

Raj and Verma (1989) reported that population growth and development of *M. persicae* on potato in India highly fluctuated where its build-up was highest in early Rabi and lowest in Kharif. Weather conditions may be high influence on population-dynamics of *M. persicae*. But **Furiatti et al. (1993)** determined the population fluctuation of *Myzus persicae* by using yellow water traps and related it with temperature and relative humidity. Highest aphid population was obtained at 18-20°C.

The significant relationship was obtained between the mean temperature of collecting days and the number of *M. persicae*.

Kashyap (1994) reported that aphid *Myzus persicae* (SuIz.) is predominant aphid species which infests seed potato crop during studies of four years revealed that the permissible limit (20 aphid/ 100 compound leaves) in crossed either in 3rd or 4th week of December depending upon the weather variables, peak aphid population were observed two weeks after crossing the permissible limit. But **Ghosh et al. (2004)** reported that aphid (*Aphis gossypii*) in *Terai* region of West Bengal was active throughout the year and reached to its highest population (94.08/leaf) in early August. Population of aphid showed significant positive correlation with average temperature, relative humidity and weekly rainfall. where're **Giordanengo et al. ((2013)** reported that in potatoes, aphids rarely reach populations which lower potato yields by their feeding alone, due to natural enemy complex including Coccinellidae, predatory bugs in genera Orius, Nabis, and Geocoris, lacewings, spiders, syrphid fly larvae, and/or predatory gall midge larvae (Cecidomyiidae), as well as aphid specific parasitoids, typically solitary koinobionts in family Aphidiidae.

Ghosh et al. (2004) reported aphid peak during early August in *Tarai* region of West Bengal and **Meena et al. (2013)** during first fortnight of September on Kharif potato. But **Shukla (2014)** recorded the periodic incidence of different sucking pests on potato during the crop season .The aphid population reached its peak level (27.17 aphids / 3 leaves) during 14th week after sowing. Results revealed that maximum activity was recorded during January and the correlation studies showed positive correlation with rainfall and relative humidity and negative correlation with both maximum and minimum temperatures.

Pandey et al. (2007) studied the population dynamics of aphids *Myzus persicae* in relation to weather parameters during 2005-06 & 2006-07 on two potato varieties viz., *Kufri Ashoka* and *Kufri Badshah* in *Terai* region. Results revealed that the first appearance of *Myzus persicae* was observed in last week of November during 2005-06 and first week of December during 2006-07 on both the varieties and the period of peak population were observed during 3rd week of January. The correlation of aphid population with temperature and relative humidity revealed significant negative

correlation with temperature and significant positive correlation with relative humidity but sunshine had no significant effect on population of *Myzus persicae*.

Nisha Shukla (2014) reported that the periodic incidence of different sucking pests on potato during the crop season was significant at different period of crop growth. The period mean revealed that the aphid population was reached to its peak level (27.17 aphids/3 leaves) during 14th weeks after sowing. The aphids were considered as sucking insect pests. Results revealed that maximum activity was recorded during January and the correlation studies were made between the incidence of major sucking insect pests and select weather parameters. Aphids showed positive correlation with rainfall ($r = 0.261$) and negative correlation with both maximum and minimum temperature. Aphids showed positive correlation with relative humidity.

2.1.2 Seasonal incidence of whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) in potato crop.

Reddy et al. (1991) recorded fluctuation of whitefly population in relation to temperature which is an important abiotic factor. They noticed that there was rapid multiplication of whitefly at 29^oC to 30^oC temperatures on cotton, while negatively associated with rainfall, relative humidity, and rainy days.

Chaudhuri et al. (2001) found that the maximum population density of whitefly on tomato (1.68 whiteflies/plant) in West Bengal during mid-February and high infestation levels were maintained from mid- February to mid-March.

Ali et al. (2004) observed the appearance of whitefly, *B. tabacii* mid-May and reached at peak in July. The lowest population was observed at the of the September. The population density of mites was the highest in early July and lowest in the second week of September. Experiment conducted at Shimoga in Karnataka by **Shivanna et al. (2011)** revealed that the population of whitefly, *B. tabaci* in brinjal was active throughout the year with peak activity of whitefly i.e. 29.50 whiteflies per three leaves during (2nd fortnight) of April. While, **Meena et al. (2013)** noticed that whitefly population during July to November and attained their peak in first and second week of September during 2006-07 (6.9 whiteflies/ 3 leaves/plant) and during 2007-08 (6.7 whiteflies/ 3 leaves/ plant), at Rajsamad in Rajasthan. **Nonita et al. (2008)** reported maximum whitefly incidence during 2nd SMW of January while minimum incidence

during 12th SMW of March. **Meena et al. (2012)** found that the infestation of shoot and fruit borer was also observed during November and December and the maximum population was observed during 6th and 7th standard week of month February.

Oommen and Kumar (2004) observed that whitefly incidence (5.8 whiteflies/5 plants) started from mid-July. Thereafter, its population increased gradually and reached to its peak (34.5 whiteflies/5 plants) during first week of September. They recorded (2.05 whiteflies/5 plants). The lowest population of whitefly during the first week of December a positive correlation was recorded with average temperature and whitefly population, whereas, it was negatively correlated with average relative humidity.

Bharadiya and Patil (2005) recorded the maximum activity of *B. tabacii* during the fourth week of October. A positive significant correlation was observed between the whitefly and maximum and minimum temperature, whereas significant negative correlation was observed between the pest and maximum and minimum relative humidity, and rainfall. The meteorological factors contributed 72.30-92.30% for the build-up of whitefly population from the direct count and from yellow sticky traps (**Saha et al. 2001**).

Paul and Konar (2005) reported that whitefly (*Bemisia tabaci* Guen.) appeared on potato crop during the first week of December and reached its peak during last week of December with environmental conditions of 17.8 to 20.2°C mean temperature and 75.2 to 77.9% mean relative humidity (R.H.) and very little rainfall. It was also observed that the pest population was negatively associated with mean temperature ($r = -0.2240$ to -0.7381) and rainfall ($r = -0.2162$ to -0.4328) whereas positively related with mean R.H. ($r = 0.0155$ to 0.6955). The population was profoundly related to climatic factors while in others, the crop age might have played an important role regarding population development of the pest. Thus, both abiotic and biotic factors are responsible for population build of whitefly on potato. But **Meena et al. (2010)** reported that the infestation of whitefly (0.8 and 1.2 white /plant) on okra was started in the first week of August and remained active throughout the crop season and its population reached at maximum (6.2 and 8.6 whiteflies/plant) in fourth and third week of September in both the years. The abiotic stress (maximum and minimum

temperature, relative humidity and rainfall) had a nonsignificant correlation coefficient with the population of whitefly.

Mandloi (2015) studied the activity period of *Aphis gossypii* Glover from October 2012 to March 2013 with two distinct peaks (11.22 and 11.66 aphid/ 6 leaves) during 7th and 11th SW (standard week) and *Liriomyza tritici* Burges was observed from October 2012 to March 2013 with three distinct peaks (44.56%, 45.95%, and 44.02%) during 10th, 11th and 12th SW respectively. While *Bemisia tabaci* Genn appeared November 2012 to March 2013 with two distinct peaks (9.84 and 11.85 flies/10cm twigs) during 7th and 9th SW. *Amrasca devastans* Ishida and *Scirtothrips dorsalis* Hood were observed during November 2012 to March 2013 with two distinct peaks (9.26 and 9.15 jassid/6 leaves) 9th and 11th SW and 7th and 9th SW (2.08 and 1.85 thrips/ 6 leaves) respectively. Analysis of correlation coefficient between abiotic factors (weather parameters) and the major insect pests, showed that population of thrips had a significant positive correlation with evening relative humidity (R.H.), while fruit borer had a significant positive correlation with rainy days.

Medina-Hernández et al. (2019) the present study in the review paper was to assess the effect of different environmental factor on the population of whitefly *Bemisia tabaci*. With this aim, we study the different works done in India and abroad during 1982 to 2017 and found that different environmental factors affect the population in different extent even variation was found in same factors in different location or different time.

2.1.3 Seasonal incidence of hopper, *Empoasca devastans* (Hemiptera: Cicadellidae) in potato crop.

Bhalani and Patel (1981) reported variation in the nymphal period of jassids, depending upon the host. He observed that at an average temperature of 27.9°C and relative humidity of 76.8 percent, the nymphal period was 8.0 days on okra, 8.38 days on cotton, 9.30 days on hollyhock and 11.20 days on eggplant. The shortest nymphal period was recorded on okra and cotton while highest (11.66) and lowest (5.55) growth index was recorded on okra and eggplant, respectively but **Shukla (1989)** observed fluctuation of *hopper* population during the different growth stage of brinjal crop grown in Meghalaya they found that the population begin to increase in the 1st week of June

and attained peak (64.28 jassids/ 3 leaves) in last week of August. It showed a positive correlation with the average temperature, mean relative humidity, and total rain fall.

It is known as hoppers, are plant feeders that suck plant sap from tender plant part. These are pest and vectors of plant viruses. is a serious insect pest (**Ahmad, 1986**) ranging from green, yellow-green to brown in color and occurring throughout the crop growing period on various crops. Adults and nymphs of feed on the underside of the leaves by sucking plant sap, which results in yellowing and curling of leaves. They also inject toxins which result in abnormal changes in marginal chlorosis and reddening or burning symptom. The blades of severely infested leaves express burning symptom and such leaves may ultimately drop down (**Rahman, 2009**). The severity of this pest depends on the occurrence of congenial weather conditions and crops.

Mahmood et al. (2002) reported that the incidence of leafhopper, showed positive and significant correlation with maximum and minimum temperatures. Relative humidity and rainfall were negatively and non-significantly correlated with population fluctuation. Sunshine was also positive by correlated but not significant.

Ratanpara et al. (1994) reported that population build trend of hopper negatively associated with temperature while positive relation was observed with sunshine.

In Haryana **Sharma and Sharma (1997)** recorded the highest population of jassid during the first week of August. While **Das et al. (2003)** reported that the incidence of jassid commenced from the 26th standard week, reached peak intensity (69.6/25 leaves) during 30th standard week i.e., last week of July.

Bhatnagar (2007) there was a negative correlation with maximum temperature and rainfall and non-significantly positive correlation with maximum temperature. Unlike others, **Meena et al. (2012)** observed the maximum incidence of jassids during 52nd Standard Week (SMW) of December and minimum was during 12th SMW of March during *Rabi* season 2009 on brinjal.

2.1.4 Seasonal incidence of thrips, *Thrips palmi* (Thysanura: Thripidae) in potato crop.

Shukla (2006) conducted a field survey to record the seasonal abundance of *Scirtothrips dorsalis* on chilli crop and increased continuously till the crop maturity

43.5 per cent. The pest did not indicate a strong correlation with temperature and relative humidity. A study was conducted to record the incidence of *S. dorsalis* on chilli (*Capsicum annuum*) initiated from the first week of September until harvesting and the peak activity was recorded in November (4.99 to 5.54 thrips/leaf) and -March (5.29 to 7.38 thrips/leaf).

Patel et al. (2009) observed a significant positive correlation of thrips with bright sunshine hours and maximum temperature, but a significant negative correlation with rainfall, and morning, afternoon and mean relative humidity and vapour pressure. The thrips population decreased with increasing of rainfall.

Rai et al. (2009) reported that the incidence of thrips commenced from 2nd week of September to first week of November and was maximum (2 thrips/ three terminal leaves) in the first week of October.

Pathipati et al. (2014) revealed that the infestation and severity of insect pests were highly influenced by weather parameters. Thrips population reached its peak (1.80/leaf) in the 52nd Standard Meteorological Week (SMW). Thrips population had a positive correlation with maximum temperature and negative correlation with minimum temperature, morning and evening relative humidity, and rainfall.

2.2 Effect of imidacloprid and flonicamid against insect pests of potato.

Morita et al. (2007) reported that flonicamid was very effective against aphids, regardless of differences in species, stages and morphs as this compound inhibited the feeding behavior of aphids within 30 min. of treatment and this antifeeding activity led to starvation and death. A study was conducted by **Nieto and Simonetta (2008)** on apples and peaches revealed that flonicamid exhibited a high control against aphids and whiteflies.

Misra (2009) screened four insecticides including flonicamid 50 WG, imidacloprid 17.8% SL, thiamethoxam 25% WG and clothianidin 50% WDG against the brown planthopper, *Nilaparvata lugens* (Stal.). Results showed that low BPH population (1.40-1.30/hill) was observed with flonicamid 50 WG at 150 g a.i. /ha with a reduction of 90.30% over untreated control.

Jalali et al. (2009) conducted a laboratory study for the toxicity of pirimicarb, imidacloprid, dimethoate, lambda-cyhalothrin, flonicamid and spinosad to the two-spot

ladybird, *Adaliabipunctata*. Results showed that flonicamid and spinosad had no lethal effects on larvae and female adults.

Wrzodak and Woszczyk (2011) reported that flonicamid used at the doses 0.14 and 0.16 kg/ha showed a very good effectiveness in the brassica plants protection against cabbage aphid. A study was conducted by **Bartual et al. (2012)** to manage the aphids *Aphis gossypii* and *Aphis punicae*, which were the most important pests of pomegranate which revealed that the new generation insecticide flonicamid was very effective in controlling aphids.

Rouhani et al. (2013) conducted the laboratory evaluation of thiamethoxam, thiacloprid and flonicamid for mortality of *A. punicae* under controlled conditions and reported that flonicamid at 0.1 mg/ml had resulted in the highest mortality.

Chandi et al. (1969) evaluated flonicamid 50WG @ 50, 75 and 100 g a.i. ha⁻¹ against sucking insect pests and predatory complex and found flonicamid @ 75 g a.i. ha⁻¹ efficacy to be higher or at par with standard checks after 3 and 7 days of spray. Flonicamid @ 75 g a.i. ha⁻¹ provided up to 73.4 per cent reduction in whitefly population and Per cent reduction of aphid was higher in flonicamid @ 75 g a.i. ha⁻¹ after 3, 7 and 10 days of spray and flonicamid was comparatively safer to predatory complex.

According to **Morita et al. (2007)** flonicamid compound inhibited the feeding behavior of aphids within 0.5 h of treatment without noticeable poisoning symptoms such as convulsion, and this antifeeding activity was not recoverable until death. The nymphs born from adults exposed to flonicamid for 3 h showed high mortality.

Konar et al. (2013) reported imidacloprid @ 30g a.i/ha was found most effective in reducing population of aphids and maximum net return was obtained from emamectin benzoate @ 18g a.i.ha-1, the cost-benefit ratio was recorded from imidacloprid-treated plots i.e. 1:12.16.

Rouhami et al. (2013) while evaluating four neonicotinoids viz. flonicamid, imidacloprid, thiamethoxam, and thiacloprid on first instar nymphs of pomegranate aphid, *Aphis punicae* passerine under laboratory conditions in Iran, revealed that imidacloprid was the most toxic chemical followed by thiacloprid, flonicamid and thiamethoxam in the decreasing order. Both imidacloprid and thiacloprid provided

highest mortality at 1ul/ml, followed by flonicamid (0.1mg/ml) and thiamethoxam (0.35mg/ml).

Ghelani et al. (2014) reported among the insecticidal treatments, flonicamid 0.02 per cent was found more effective against all major sucking pests and imidacloprid 0.0089 per cent against jassid and thiamethoxam 0.01 percent were found effective against thrips on *Bt* cotton.

2.3 Bioefficacy of some novel insecticides as foliar spray and seed treatment against insect pests of potato.

Gupta et al. (1998) reported that foliar application of imidacloprid 200 SL was highly effective against sucking pests of cotton especially against aphids and leafhoppers but **Kumar and Santharam (1999)** observed that the foliar application of imidacloprid 200 SL at 200 ml/ha was highly effective against sucking pests of cotton. **Sesha Mahalakshmi (2007)** reported that the foliar application of imidacloprid 200 SL (0.33 ml/L) was highly effective against sucking pests and **Preetha et al. (2012)** reported that imidacloprid 17.8 SL was quite promising in reducing the population of aphids and leafhoppers without any phytotoxic symptoms. **Ahmed et al. (2014)** reported that imidacloprid was safer to natural enemies and toxic for the sucking pests.

Khairi et al. (1992) conducted experiment on *Callosobruchus chinensis* (Linn.) in cowpea to test six vegetable oils viz., castor, mustard, groundnut, sesamum, coconut and sunflower. All the oils caused significant mortality in adults after three days of treatment. The castor oil at 1.0 ml/100 g seeds was found to be the most effective causing 80.7 per cent mortality of adults. Castor oil @ 1.0 ml/100 g seeds.

Chinniah et al. (2000) observed the efficacy of some neonicotinoids against aphid of okra and reported that imidacloprid 17.8 SL @ 50 g a.i. ha⁻¹ was found the most effective neonicotinoid insecticide against aphid. Resulted in least aphid infestation and 84.54 % reduction of population over control. None of the neonicotinoids have an adverse effect on natural enemies of aphid in okra ecosystem.

Fenigstein et al. (2001) conducted an experiment and observed the effects of vegetable (seed) oils, peanut, cottonseed, castor, soybean, and sunflower, on adult and immature stages of the sweet potato whitefly (*Bemisia tabaci* (Gennadius) [Hemiptera: Aleyrodidae]) in the laboratory. Peanut oil was the most effective for all

tested effects, followed by cottonseed oil, which was significantly less effective than peanut and castor oils when applied directly to eggs. As direct sprays to larvae, soybean and sunflower oils resembled castor oils, but their residues were less effective against all stages.

Singh et al. (2003) while evaluating 7 insecticides as a single spray during pink bud stage against peach leaf curl aphid *B. helichrysi* in Uttarakhand reported imidacloprid (0.007%) and thiamethoxam (0.05%) effective with 0.13 and 0.31 per cent curled leaves, respectively, in the first year where as the respective figures for the next year were 0.00 and 0.55 per cent. In control, the per cent curled leaves recorded were 58.48 and 69.84, during 1st and 2nd year, respectively. **Mishra and Zafer (2005)** also reported that imidacloprid treated peach trees showed lowest aphid incidence and better yield in comparison to all other treatments combinations and control.

Lobna (2012) studied the initial and residual efficacy of three neonicotinoids as a seed treatment at two rates 2.45 and 4.9 g a.i./kg seed against four early-season sucking pests *Thrips tabaci*, *Aphis gossypii*, *Empoasca spp.*, *Bemisia tabaci*, adult and immature). Data obtained revealed that no insecticide tested as seed treatment provided 100% reduction at the tested rates against the four sucking pests. On the other hand, imidacloprid (Gaucho) seemed to be more effective than the two thiamethoxam formulations and exhibited excellent initial reduction within the 2-week post-treatment, evoking remarkably high reduction and reached 89.9, 90.5, 100, 95, and 96.3% for thrips, aphid jassid, and whitefly adult and immature, respectively when applying the recommended rate. Late on, Gaucho exhibited satisfactory residual effectiveness and recorded an overall average reduction after 8 weeks reached 65.3, 53.7, 48.1, 64.2 and 75% for the prementioned sucking pests respectively.

Naggar et al. (2013) in a study on the field evaluation of imidacloprid and thiamethoxam against sucking insects of cotton found that treatments with imidacloprid and thiamethoxam as foliar applications were highly effective against aphids and jassids (up to 14 days), while the effect was moderate on the whitefly population (mature and immature stages).

Ghosal et al. (2013) conducted an experiment to observe the efficacy of some neonicotinoids against aphid of okra, *A. gossypii* Imidacloprid (50 g a.i. / ha),

thiamethoxam (50g a.i. / ha) and acetamiprid (40 g a.i. /ha) were found effective recording aphid infestation 1.78, 1.80 and 1.61 respectively, as compared to control (11.53). Reduction of aphid population over control was 84.55, 84.36 and 84.25per cent, respectively.

Bharpoda et al. (2014) evaluated nine synthetic insecticides against sucking insect pest's viz., leaf hopper (*Amrasca biguttula biguttula* Ishida), whitefly (*Bemisia tabaci* Gennadius), thrips (*Thrips tabaci* Lindemann) and aphid (*Aphis gossypii* Glover) in cotton variety RCH-2 Bt (BG-II) during three consecutive years i.e. 2009-10, 2010-11 and 2012-13. Among the different insecticides, imidacloprid 17.8 SL @ 0.008% (7.50 aphid and 1.47 whitefly/ leaf), thiamethoxam 25 WG @ 0.0125% (1.22 leaf hopper/ leaf) and diafenthiuron 50 WP @ 0.05% (1.43 thrips/ leaf) found more effective and safer to the natural enemies viz., *Chrysoperla carnea* (adult), spiders and coccinellids (grubs and adult).

Patil et al. (2014) conducted field experiment to evaluate and validate the efficacy of some new insecticides against sucking insect pest's viz., leafhopper, aphid, andwhitefly in okra. This study revealed that thiamethoxam (0.006%) was found to be the most effective against aphids resulting in 2.14 aphids/leaf, followed by lambda-cyhalothrin (0.004%) 2.40 aphids/leaf as compared with control 8.69 aphids/leaf. While thiamethoxam (0.006%) was effective against leafhoppers population resulting in 3.23 leafhoppers/leaf followed by thiamethoxam (0.008%) 3.94 leafhoppers/leaf as compared with control (11.49 leafhoppers/leaf). Also, in the case of whitefly the effective treatment recorded was thiamethoxam (0.006%) recording 0.48 whiteflies/leaf in comparison to 4.57 whiteflies/leaf in control. The recommended doses of insecticides were found more effective than other doses.

Tomar et al. (2017) evaluated a combination of two different groups of chemical insecticides against whitefly and other sucking insect pests which occur simultaneously on potato crop. Results obtained indicated that whitefly could effectively be controlled by three foliar sprays first and third of diafenthiuron @ 350 g. a.i. /ha.

Kukvaya et al. (2018) carried out an experiment on bio-efficacy of insecticides against sucking pest of *Vigna aconitifolia*. The results revealed that out of ten treatments, imidacloprid 17.8 SL @ 0.005 was found highly effective for the control of

jassids and thrips at par with acetamiprid 20 SP @ 0.004% while thiamethoxam 25 WG @ 0.005 was found highly effective against whitefly at par with imidacloprid 17.8 SL @ 0.005%. The control treatment of nonsprayed condition was found least effective for the control of jassids, whitefly and thrips.



*Materials
and
Methods*



The present study was conducted in Vegetable Research Center (VRC), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during the winter season of the year 2018-19. The details of material used, experimental procedures followed and statistical techniques adopted during the course of the investigation is as under.

3.1 Experimental site

The field experiments were carried on “**Management of insect pest of potato with some novel insecticides**” at Vegetable Research Center (VRC), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar (Uttarakhand) During September 2018 to March 2019. Geographically it is situated at 29°N and 79°E latitude and longitude respectively, with a height of 243.8 m above mean ocean level (MSL). Pantnagar falls under humid Subtropical zone.

3.2 Meteorological considerations

Pantnagar has humid sub-tropical climate with hot dry summer, hot and wet rainy season and cold winters. It is situated near the foothills of Shivalik range of Central Kumaon Himalayas. It is part of the *Tarai* region. The temperature may go up to 4 °C during winters whereas summer temperature may reach 41 °C. The mean annual rainfall is 134 cm, nearly 80-90 of which is received from end of June to October. The average annual rainfall of 1350 mm takes place from July to end of September. The monsoon generally sets around third to the fourth week of June to end of September. The maximum and minimum daily temperature in summer and winter may reach up to 43°C and -0.05°C, respectively. Frost generally occurs between ends of December to January last. The soil of experimental field was clay loam in nature with a pH of 6.8. The weekly average weather data during the study was obtained from Meteorological observatory located at Norman E. Borlaugh Crop Research Center, Pantnagar.

However, the total rainfall and its distribution are subjected to large variation. The mean relative humidity (R.H.) remains nearly constant about 80-90 per cent (7 AM) from mid-July to the end of February and afterward steadily decreases to 50% by the first week of May and remain at this level till June. Records of minimum and maximum temperatures,

relative humidity and rainfall during the period of experiment were collected from November to February 2018-19 from University Meteorological observations.

3.3 Physical properties of soil of experimental field

The soil of experimental field is Sandy loam in nature with a pH of 6.8. The soil comes under mollisols at Pantnagar. The soil appears light brown in color and adequate drainage and optimum water holding capacity.

3.4 Experimental Procedures

3.4.1 Field preparation

The experimental field was ploughed one time with the help of tractor mounted disc harrow. Each ploughing was followed by levelling with the help of leveler. Pre-planting irrigation were given to ensure suitable moisture in the soil.

3.4.2 Planting

The healthy tubers of potato Kufri Surya were taken and the tubers were sown in 6 different plots of size 4x5 m² (for seasonal incidence) and 3x2 m² (chemical management) respectively. Planting was done at spacing 45x30 cm². In all these, normal recommended agricultural practices were followed.

3.5 Experiment No - 1

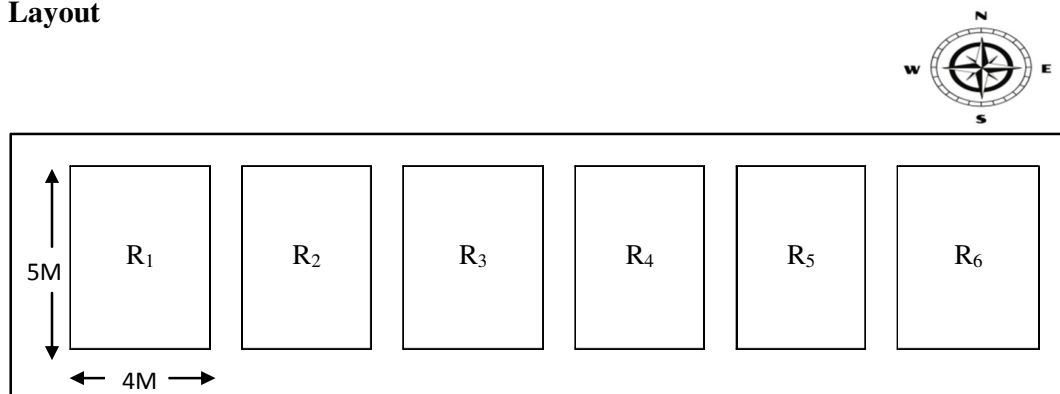
3.5.1 To study seasonal incidence of various insect pests and mite in potato crop in Tarai region of Uttarakhand

All recommended agronomic practices were followed for growing healthy potato crop for this region. No insect pest management strategies were applied to the crop for the management of insect pests. The data of seasonal incidence of major insect pest of Potato was recorded weekly interval basis till the harvesting of crop.

3.5.2 Experiment Details

- Replications : 6
- Plot size : 5x4 m²
- Variety : Kufri Surya
- Date of sowing : 23/October/2018
- Spacing : 45X30 cm

Layout



3.5.3 Observation procedure

Each plot containing seven rows, two plants from each row, and total 14 plants per plot were selected. Leaf from upper, middle and lower part of plant were counted.

3.5.4 Observation recorded

Record of insect pests and natural enemies on potato crop:

Population of insect pests and natural enemies were recorded at weekly interval from 14 plants per plot.

1. Number of aphids per 14 plants per week.
2. Number of white flies per 14 plants per week.
3. Number of jassids per 14 plants per week.
4. Number of thrips per 14 plants per week.
5. Number of natural enemies (coccinellid, spider, rove beetles) per 14 plants per week.

3.6 Experiment No - 2

3.6.1. Comparison efficacy of imidacloprid and flonicamid against insect pests of potato.

The potato variety taken for experimentation was “Kufri Sadabahar” tubers were sown in the field in a randomized block design (RBD) on 23-10-2018. The bioefficacy of flonicamide and imidacloprid as foliar application were observed against insect pests of potato.

3.6.2. Experiment Details

Particular	:	Details
➤ Experimental design	:	RBD (Randomized Block Design)
➤ Treatments	:	5
➤ Replication	:	5
➤ Total No. of plots	:	25
➤ Plot size	:	3x2 m ²
➤ Number of rows per plot	:	5
➤ Variety	:	Kufri Sadabahar
➤ Spacing	:	45 X 30 cm
➤ Date of sowing	:	23/October /2018
➤ Season	:	Winter

3.6.3 Treatments details

Treatments	Insecticide	Doses
T ₁	Untreated	-
T ₂	Imidacloprid 17.8 SL @ 3ml/10lits	150 ml / ha
T ₃	Imidacloprid 17.8 SL @ 3ml/10 lits + repeat at 15 days	150 ml / ha
T ₄	Flonicamid 50 WG @ 3g / 10 lits	150 g / ha
T ₅	Flonicamid 50 WG @ 3g / 10 lits + repeat at 15 days	150 g / ha

3.6.4 Observation recorded

1. Spraying was done after attaining the Economic Threshold Level of insects. It was 8 in aphids / leaves, 8-10 in whitefly / leave, 2-3 in jassid /leaves and 7-8 in thrips /leave.
2. Weekly observations were conducted to study the Bioefficacy of chemicals on aphid, whitefly, hopper, thrips and mites. Effects of chemicals on natural enemies have also studied. observations were recorded were recorded after 2nd, 4th and 6th days of spray on 10 tagged / plot (3 leaves lower, middle and upper)

Layout

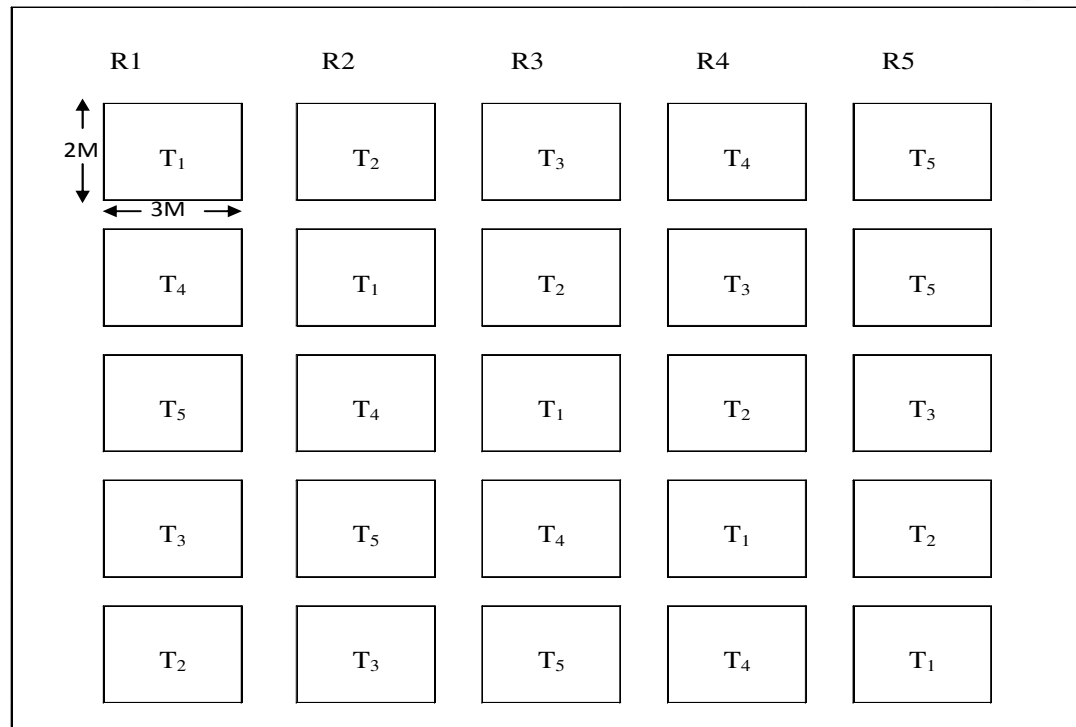
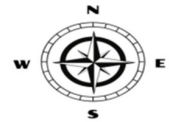
Twenty five plots were demarcated and arranged in randomized block design with five replications of five treatments each.

Treatment (T) - 5

Replication (R) – 5

Randomizations have been done with randomized number table.

2. Layout of the experiment showing the allocation of treatment of imidacloprid and flonicamid against insect pests of potato.



3.7. Experiment - 3

3.7.1 Bioefficacy of some novel insecticides as foliar spray and seed treatment against insect pests of potato.

The potato variety taken for experiment was “Kufri Sadabahar” tubers were sown in the field in Randomized Block Design (RBD) on 23-10-2018. The bio-efficiency as seed treatment or foliar spray of insecticide against major sucking pest insect were studied.

3.7.2 Experiment Details

Particular	:	Details
➤ Experimental design	:	RBD (Randomized Block Design)
➤ Treatments	:	7
➤ Replication	:	5
➤ Total no. of plots	:	35
➤ Plot size	:	3x2 m ²
➤ Number of rows per plot	:	5
➤ Variety	:	Kufri Sadabahar
➤ Spacing	:	45 X 30 cm ²

3.7.3 Treatments details:-

Treatments	Insecticide	Doses
T ₁	Control	-
T ₂	Seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar Spray of imidacloprid @60 g a.i./ha at 85% emergence + second spray with thiamethoxam 25 WG @ 100g a.i./ha	60 g /ha 100 g / ha
T ₃	Foliar spray of diafenthiuron 50 WP 350 g a.i. at 85 % emergence	350 g /ha
T ₄	Foliar spray of diafenthiuron 50 WP 350 g a.i. at 85 % emergence followed by second spray of diafenthiuron after 10 days	350 g / ha
T ₅	Foliar spray of castor oil @ 0.05 % at 85 % emergence	250 ml/ha
T ₆	Foliar spray of diafenthiuron 50 WP 350 g a.i at 85% emergence mixed with castor oil @ 0.05 %	350 g /ha 250 ml /ha
T ₇	Foliar spray of diafenthiuron 50 WP 350 g a.i. at 85% emergence mixed with castor oil @0.05% by second spray with diafenthiuron after 10 days	350 g /ha 250 ml /ha

3.7.4. Observation recorded

Weekly observations were conducted to study the bioefficacy of chemicals on aphid, whitefly, hopper and mites. Observations were recorded after 24, 48 and 72 hours of spray on 10 tagged / plot (3 leaves lower, middle and upper)

3.7.5. Yield of potato (kg/ha)

The weight of potato for each treatment and the total yield was calculated adding the yield from each treatment. The yield then converts into per hectare basis by the following formula as described by **Usman *et al.* (2012)**

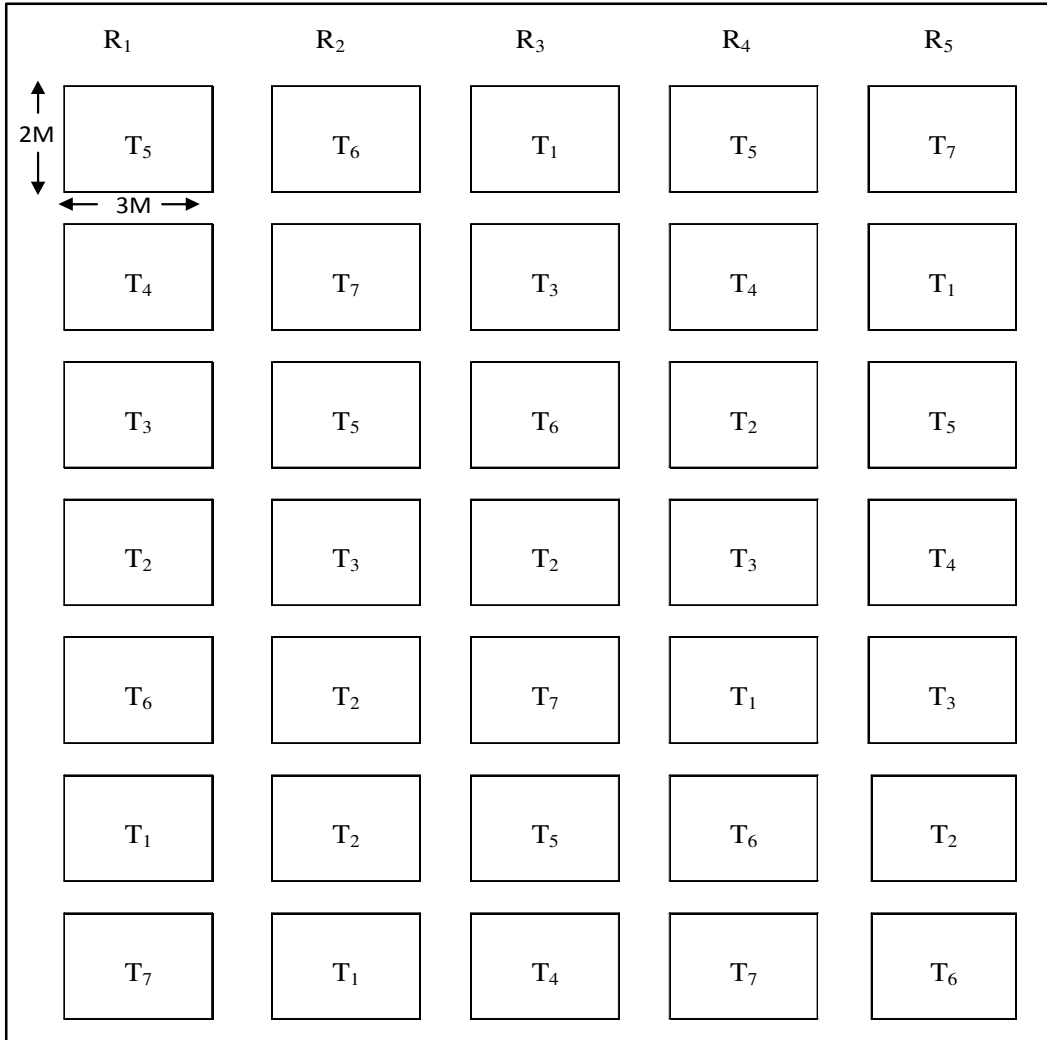
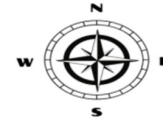
$$Yield(Kg /ha) = \frac{Yield/Plot}{Plot\ size} \times 1000$$

3.8 Statically Analysis

The results obtained from field observations were analyzed using the RBD (SPSS and STPR) program as given by **Panse and Sukhatme (1985)**. According; the data collect from potato crop pertaining to various insect pests were subjected to analysis under Randomized Block Design. After determination of critical differences between the treatments means at (0.5%) percent probability, critical difference was calculated in order to compare the treatment means.

Correlation of natural enemies with insect pests have been calculated with help of (SPSS) Statistical program.

3. Layout of the experiment showing the allocation of treatment of insecticides.





*Results
and
Discussion*



The experiments on various aspects of present study entitled “**Management of insect pests of potato with some novel insecticides**” were conducted during *rabi* season of 2018-19. In the present investigation, field studies were conducted at the experimental area of Vegetable Research center (VRC), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar (Uttarakhand), the results are presented under following heads:

1. To study seasonal incidence of various insect pests and mite in potato crop in *Tarai* region of Uttarakhand.
2. Comparison of imidacloprid and flonicamid against insect pests of potato.
3. Bioefficacy of some novel insecticides as foliar spray and seed treatment against insect pests of potato.

During the course of present study, 14 species of insect pests belonging to 14 genera, 10 families and 6 orders were found to be associated with potato. Associated to these pests, 8 predators of aphids belonging to different family and 5 parasitoid's belonging to families Eulophidae, Ichneumonidae, Braconidae and Pteromalidae were also reported. Out of 11 potato insect pests collected, aphid (*Myzus persicae*), white fly (*Bemisia tabaci*) and potato leaf hopper (*Empoasca devastans*) were the predominant species infesting the potato crop.

Table 4.1: Biodiversity of arthropods fauna in potato ecosystem.

Sl.No.	Common name	Pest species	Order	Family
1.	Aphid	<i>Myzus persicae</i> (Sulzer)	Hemiptera	Aphididae
2.	Potato aphid	<i>Macrosiphum euphorvae</i> (Thos.)	Hemiptera	Aphididae
3.	Cotton Aphid	<i>Aphis gossypii</i> (Glover.)	Hemiptera	Aphididae
4.	Hopper	<i>Amrasca bigutulla bigutulla</i> (Ishida.)	Hemiptera	Cicadellidae
5.	Potato leafhopper	<i>Empoasca fabae</i> (Harris)	Hemiptera	Cicadellidae
6.	Leafhoppers	<i>Empoasca devastans</i> (Distant)	Hemiptera	Cicadellidae
7.	Whitefly	<i>Bemisia tabaci</i> (Gen.)	Hemiptera	Aleyrodidae

8.	Thrips	<i>Thrips palmi</i> (Karny)	Thysanoptera	Thripidae
9.	Epilachna beetle	<i>Epilachna vigintioctopunctata</i> (Fab.)	Coleoptera	Coccinellidae
10.	Tobacco caterpillar	<i>Sodoptera litura</i> (Fab.)	Lepidoptera	Noctuidae
11.	Mealy bugs	<i>Maconellicoccus hirsutus</i>	Hemiptera	Pseudococcidae
12.	Green stink bug	<i>Nezara viridula</i> (Linn.)	Hemiptera	Pentatomidae
13.	Mole cricket	<i>Gryllotalpa</i> spp.	Orthoptera	Gryllotalpidae
14.	Grasshoppers	<i>Schistocerca americana</i> (Dury)	Orthoptera	Acrididae

Predators:

Sl.No.	Common name	Pest species	Order	Family
1.	Ladybird beetle	<i>Coccinella septumpunctata</i> (Linn.)	Coleoptera	Coccinellidae
2.	Three-striped Lady Beetle	<i>Brumoides saturalis</i> (Fab.)	Coleoptera	Coccinellidae
3.	Lacewing	<i>Chrysopa carnea</i>	Neuroptera	Chrysopidae
4.	Spider	<i>Neoscona</i> spp.	Araneae	Hypochilidae
5.	Lynx spider	<i>Oxyopes</i> spp.	Araneae	Oxyopidae
7.	Rove beetles (Staphylinid beetle)	<i>Paederus dermatitis</i>	Coleoptera	Staphylinidae
8.	Syrphid flies	<i>Allograpta obliqua</i> (Say.)	Diptera	Syrphidae

Parasitoids:

1.	<i>Apanteles litae</i>	Hymenoptera	Braconidae
2.	<i>Chelonus</i> sp.	Hymenoptera	Braconidae



Sowing of potato



Virus infection on potato plant



Insecticide spray on potato crop



Harvesting of potato



Plates No.2. A view of Experimental layout

A view of trial on bioefficacy of novel insecticides against sucking pests on variety Kufri Sadabahar, at Vegetable Research Center, Pantnagar



Spider
Oxyopes satticus



Spider
Neoscona sps.



Syrphid flies
Allograpta obliqua Say.



Rove beetles
Paederus dermatitis



Apanteles sp.



Chelonus sp.

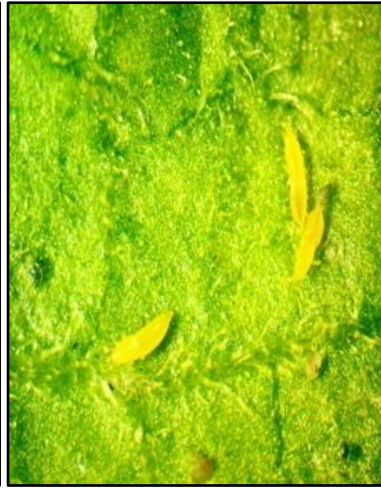
Plate No. 3. Beneficial insects associated with potato crop during crop season 2018-19



Hopper
Empoasca devastans Distant



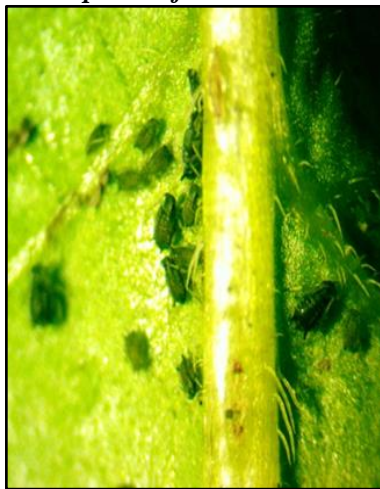
Hopper
Empoasca fabae Harris



Thrips
Thrips palmi Karny



Whitefly
Bemisia tabaci Gennadius



Cotton Aphid
Aphis gossypii Glover.



Aphid
Myzus persicae Sulz.



Grasshoppers
Schistocerca americana
Dury



Mealybugs
Maconellicoccus hirsutus
Gr.



Colorado potato beetles
Leptinotarsa sp.

Plates No. 4. Major and minor insect pests of potato crop



Adult

Eggs

Grub

Pupa

Ladybird beetle
Coccinella septumpunctata



Brumoides suturalis



Cheilomenes sexmaculata



Micraspis discolor

Plates No. 5. Different species of ladybird beetles recorded on sucking pests of potato.

4.3 To study seasonal incidence of various insect pests and mite in potato crop in Tarai region of Uttarakhand.

Potato crop was planted on 23-10-2018 (43th week) during *Rabi* season. During the course of study regular monitoring was done and recorded many insect pests infesting the crop associated with the seasonal fluctuation of insect pest. Among them grasshoppers were the first insects to appear in the potato field after planting and appearance was marked from 44th standard week of 2018 to 45th standard week of 2018. Next to this, the alate form of aphid, (*M. persicae*) appeared from 47th to 6th standard week during the year 2018-19. White fly (*Bemisia tabaci*) appeared from 47th to 4th standard week during the crop season, potato leaf hopper (*Empoasca devastans*) 47th to 3rd standard week and thrips (*Thrips palmi*) appeared from 51th to 6th standard week during the crop season during the year 2018-19.

During the crop season the incidence of predators of aphid's viz. *Coccinella septempunctata*, *Paederus dermatitis*, *Oxyopes saticus* and hymenopterans parasitoids were from 48th standard week of 2018 to 4th standard week of 2019.

4.3 Symptoms of damage of insect pests in potato crop.

4.3.1 Aphid (Hemiptera: Aphididae)

During present study potato crop was infested with different spp. of aphid *i.e.* *Myzus persicae* (Sulz.), *Aphis gossypii* (Glover.), and *Macrosiphum euphorvae* (Thos.). Infestations were sporadic in occurrence and rarely severe enough to kill plants. Damage is caused by both nymphs and adults sucking sap from foliage, especially from the terminal growth. New growth may become stunted and curled. The transmission of tomato and potato diseases, such as mosaics, leaf roll, and spindle tuber, cause more injury to the plants than sucking the sap.

4.3.2 Whitefly, *Bemisia tabaci* (Gen.) (Hemiptera: Aleyrodidae)

Whitefly reduce the life of the crop by sucking the cell sap, as a result of its infestation chlorotic spots were formed on the leaf surface. When the insect population was maximum, these chlorotic spots coalesce until the leaves appear yellow with green veins. *Bemisia tabaci* is known as a vector of viral disease and incidence of viral disease was also observed during the study.

4.3.3 Potato leafhopper (Hemiptera: Cicadellidae)

The symptom of *Empoasca fabae*, *Empoasca devastans*, primarily adults, causes feeding injury to potato plants. They feed on the underside of leaflets. Injury starts with a yellowing along leaflet margins with a slight rolling. This slight injury is soon followed by a gradual browning starting at the leaflet's tip and margin (hopper burn), and extending basically until the leaflet is all dead and desiccated. The browning is due to cellular death or necrosis. Defoliation will occur. The result is a reduction in yield. No effect on tuber quality has been reported by potato leafhopper.

4.3.4 Thrips, *Thrips palmi* (Thysanoptera: Thripidae)

Damage by *Thrips palmi* is unlike that caused by many other species of thrips when populations are high; their feeding causes a silvery or bronzed appearance on the surface of the plant, especially on the midrib and veins of leaves. Leaves and terminal shoots become stunted and deformed. Damaged leaves generally show a darkened, glossy, pearly appearance.

4.3.5 Mealy bugs, *Maconellicoccus hirsutus* (Hemiptera : Pseudococcidae)

Mealybugs damage plants by sucking sap from tender leaves and petioles. They excrete honeydew on which sooty mould develops. Severely infested leaves turn yellow and gradually dry. Severe attack can result in shedding of leaves and inflorescences, reduced tuber. honeydew, sooty mould and waxy deposits may cover leaves reducing photosynthetic efficiency and may lead to leaf drop. The honeydew attracts ants, which collect the honey and protect indirectly mealybugs from natural enemies. Some mealybugs inject toxic substances while feeding causing deformation of the plant (e.g. the cassava mealybug). Some species transmit viruses (e.g. the pineapple mealybug).

4.4 Population dynamics of major insect pests of potato

4.4.1 Population dynamics of aphid

The collected data on population dynamics of *Myzus persicae* and *Aphis gossypii* was studied on Kufri Surya cultivar of potato in relation to weather parameters at VRC Pantnagar during 2018-19 presented in **Table 4.2**

Perusal at table revealed that the initial appearance of potato aphid *Myzus persicae* (0.84 aphids/3 leaves) was observed during 47th standard week i.e. 4th week of

November. The population of the aphid increased in the 50th standard week (8.55 aphids/3 leaves) when the maximum and minimum temperature was 22.60°C and 6.6°C, maximum and minimum relative humidity was 94.6% and 60.4%, rainfall was 0.08 mm, sunshine hours was 6.3 hrs. and wind velocity was 1.09 km/hr. followed by 49th standard week (3.72 aphids/3 leaves).

There was sudden rise in aphid population (10.54 aphids/3 leaves) during 51th standard week of 2018 when the maximum and minimum temperature was 22.5°C and 5.0°C, maximum and minimum relative humidity was 96.6% and 50.7%, rainfall was 0.00 mm, sunshine hours was 6.8 hrs. and wind velocity was 2 km/hr. and attained its peak in the 2nd 11.85 aphids/3 leaves and 3rd 12.13 aphids/3 leaves standard week of 2019 when the maximum and minimum temperature was 21.6°C, 21.7 and 5.7, 5.7°C), maximum and minimum relative humidity was 94%, 93% and 57%, 53%, rainfall was 0.00 mm and 0.00 mm, sunshine hours was 5.7 hrs. and 6.1 hrs. and wind velocity was 0.00 and 1.2 km/hrs. followed 52st standard week i.e. 4th week of December Subsequently, the population of aphid (11.62 aphids/3 leaves) shows a decreasing trend during 1st standard week of 2019 when the maximum and minimum temperature was 21.3°C and 6.1°C, maximum and minimum relative humidity was 91% and 60%, rainfall was (0 mm), sunshine hours was 6 hrs. and wind velocity was not recorded.

There was decrease in aphid population 6.43 aphids/3 leaves during 4th standard week of 2019 when the maximum and minimum temperature was 20.5°C and 8.6°C, maximum and minimum relative humidity was 88% and 50%, rainfall was 14.2 mm, sunshine hours was 3.8 hrs. and wind velocity was 4.3 km/hr. and slow decrease its minimum 3.27 aphids/3 leaves in the 6th week of February Moreover, a marked when increase in the population of alate forms of aphid was noticed with the maturity of crop. It then migrated to other vegetable crops.

The decrease in the population of *M. persicae* in the 4th week of December was probably due to considerable rainfall (14.2 mm) which lead to large scale of aphid mortality due to washing off and drowning. The adverse effect of rainfall on the population of aphid was earlier demonstrated by **Narang et al. (1983)**. According to them significantly and suddenly stimulated rainfall of 1.0 and 2.0 cm reduced aphid population by 45.47- 66.43%. The reduction was greater at the higher rainfall than the lower rainfall. The aphid population ranged from 0.80 to 11.5 nymphs and adults per

Table 4.2: Mean population of *Myzus persicae* in relation to weather parameters in potato (2018-19) - Pantnagar, Uttarakhand

Month	Date	Standard week	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sun-Shine Hrs.	Wind velocity (km/hr.)	Mean
			Max.	Min.	07-12 am	14-12 pm				
November	16	46	26.5	11.8	93.3	63.1	0.0	6.5	2.3	0.00
November	23	47	26.3	10.5	93.4	54.3	0.0	7.7	1.8	0.84
November	30	48	26.4	10.7	94.6	60.6	0.0	6.4	1.9	1.62
December	07	49	23.8	7.8	92.6	61.0	0.0	6.2	1.8	3.72
December	15	50	22.6	6.6	94.6	60.4	0.8	6.3	1.9	8.55
December	23	51	22.5	5.0	96.6	50.7	0	6.8	2	10.54
December	30	52	20.3	2.7	97.1	51.9	0	6.7	2	11.62
January	06	1	21.3	6.1	91	60	0	6	0	10.99
January	13	2	21.6	5.7	94	57	0	5.7	0	11.85
January	20	3	21.7	5.7	93	53	0	6.1	1.2	12.13
January	27	4	20.5	8.6	88	50	14.2	3.8	4.3	6.43
February	04	5	20.9	7.0	93	63	0	6.1	1.6	5.11
February	11	6	21.1	9.1	95	66	15	4.7	3.4	3.27
Correlation			-0.721**	-0.915**	0.133	-0.507	-0.178	-0.094	-0.447	

*Significant at p= 0.01 level; ** Significant at p= 0.05 level; Max-Maximum temperature; Min.- Minimum temperature; Mean- population of aphid (no. per leaf)

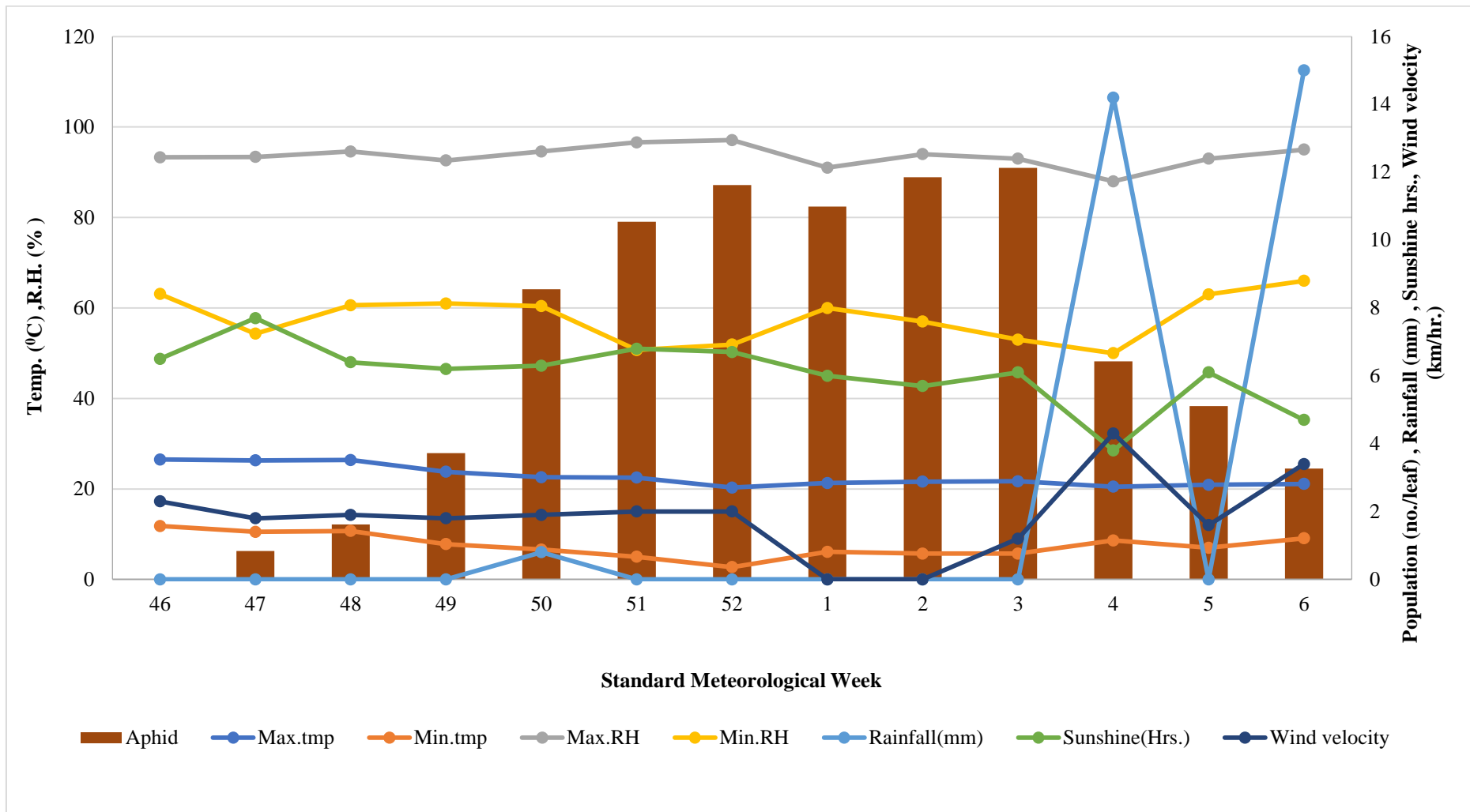


Fig. 4.1. Mean population of *Myzus persicae* in relation to weather parameters in potato (2018-19) - Pantnagar, Uttarakhand

plant with seasonal mean of 5.14 aphids /plant. It first appeared on the crop in the 2nd week of December with a mean population of 0.80 aphids /plant. Thereafter the density of aphid increased gradually with a peak of 11.5 aphids /plant in the last week of January as reported by **Nag (2016)**. The present findings are also in agreement with those of **Shrivastava et al. (1971)**, **Pandey et al. (2007)** and **Sarkar et al. (2008)**. They reported peak activity of aphid during second fortnight of January. On the contrary, **Rashid et al. (2013)** observed peak density in the last week of February and **Saljoqi (2009)** during third week of March. **Ghosh et al. (2004)** reported aphid peak during early August in *Tarai* region of West Bengal and **Meena et al. (2013)** during first fortnight of September on Kharif potato. **Bijur and Verma (1986)** showed a significant negative correlation between aphid and maximum temperature and positive with wind speed.

4.4.1.1 Correlation between *Myzus persicae* (Sulz.) and weather parameters

The compiled data on population dynamics of aphid in relation to weather parameters at VRC Pantnagar during 2018-19 presented in **Table 4.2**. showed non-significant negative correlation with minimum relative humidity (-0.507) rainfall (-0.178), sun-shine hr. (0.094), wind velocity (-0.447), significant negative correlation with maximum temperature (-0.721**), minimum temperature (-0.915*), minimum temperature (-0.721**) and minimum relative humidity (-0.915*), There is a non-significant positive correlation with maximum relative humidity (0.133).

4.4.2. Population dynamics of whitefly (*Bemisia tabaci* Gennadius)

The compiled data on population dynamics of *Bemisia tabaci* was studied on Kufri Surya in relation to weather parameters at VRC Pantnagar during 2018-19 is presented in **Table 4.3**

The initial appearance of 3.25 whitefly/3 leaves was observed during 47th standard week of 2018 *i.e.* 4th week of November. The population of the whitefly gradually increased in the 49th standard week of 2018 (9.40 whitefly/3 leaves) when the maximum and minimum temperature was 23.8^oC and 7.8^oC, maximum and minimum relative humidity was 92.6% and 61.0%, rainfall was 0.0 mm, sunshine hours was 6.2 hrs. and wind velocity was (1.8 km/hr.). followed by 48th standard week (5.27 whitefly/3 leaves), when the maximum and minimum temperature was 26.4^oC and 10.7^oC, maximum and minimum relative humidity was 94.6% and 60.6%, rainfall was (0.0 mm), sunshine hours was 6.4 hrs. and wind velocity was 1.9 km/hr.

Table 4.3: Mean population of *Bemisia tabaci* in relation to weather parameters in potato (2018-19) - Pantnagar, Uttarakhand

Month	Date	Standard week	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sun-Shine Hrs.	Wind velocity (km/hr.)	Mean
			Max.	Min.	07-12 am	14-12 pm				
November	16	46	26.5	11.8	93.3	63.1	0.0	6.5	2.3	0.00
November	23	47	26.3	10.5	93.4	54.3	0.0	7.7	1.8	3.25
November	30	48	26.4	10.7	94.6	60.6	0.0	6.4	1.9	5.27
December	07	49	23.8	7.8	92.6	61.0	0.0	6.2	1.8	9.40
December	15	50	22.6	6.6	94.6	60.4	0.8	6.3	1.9	11.13
December	23	51	22.5	5.0	96.6	50.7	0	6.8	2	15.46
December	30	52	20.3	2.7	97.1	51.9	0	6.7	2	10.70
January	06	1	21.3	6.1	91	60	0	6	0	9.05
January	13	2	21.6	5.7	94	57	0	5.7	0	1.51
January	20	3	21.7	5.7	93	53	0	6.1	1.2	3.41
January	27	4	20.5	8.6	88	50	14.2	3.8	4.3	0.30
February	04	5	20.9	7.0	93	63	0	6.1	1.6	0.00
February	11	6	21.1	9.1	95	66	15	4.7	3.4	0.00
Correlation			-0.061	-0.557*	0.455	-0.327	-0.428	0.439	-0.243	

*Significant at p= 0.01 level; ** Significant at p= 0.05 level; Max-Maximum temperature; Min.- Minimum temperature; Mean- population of whitefly (no. per leaf)

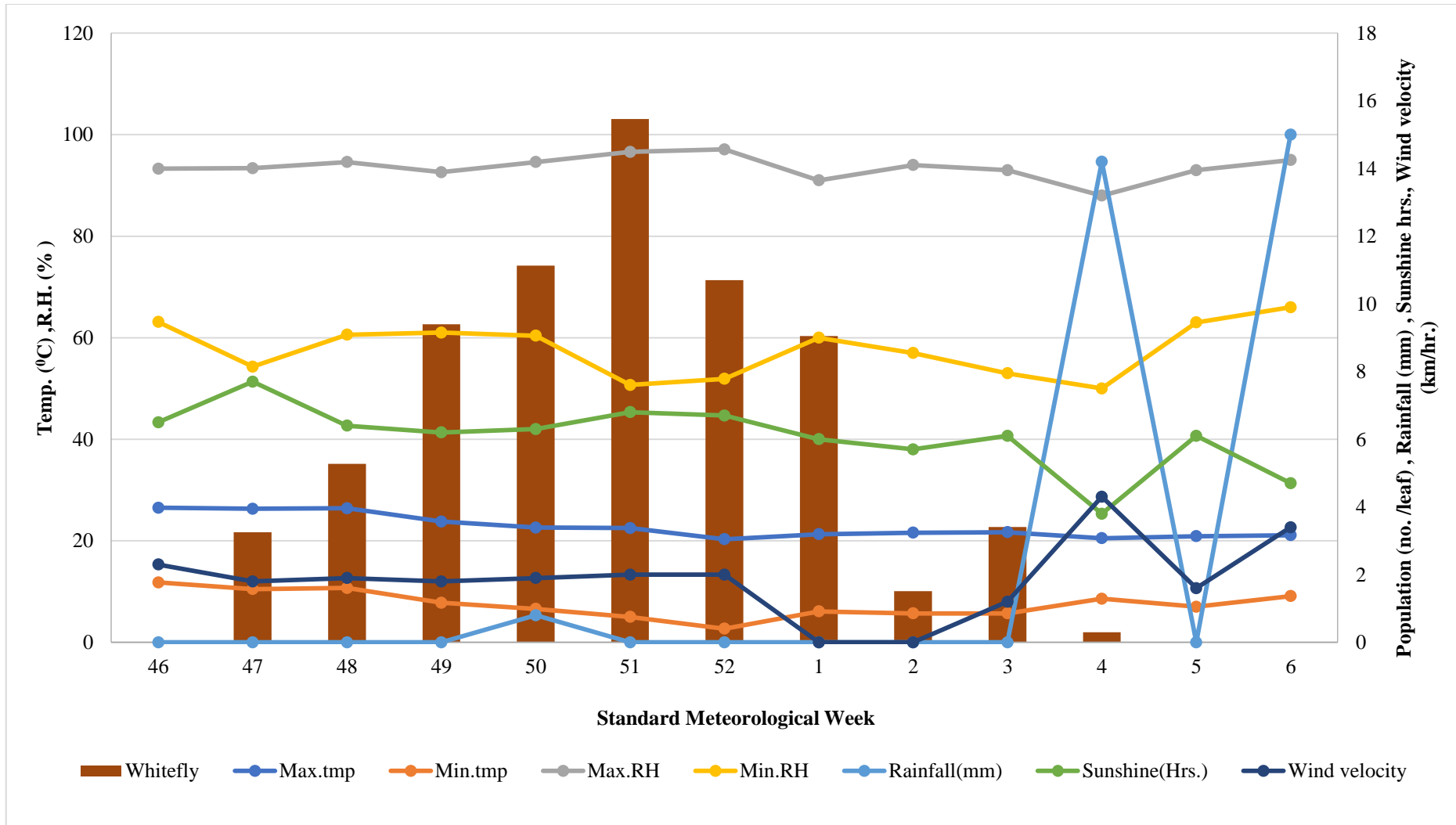


Fig 4.2. Mean population of *Bemisia tabaci* in relation to weather parameters in potato (2018-19) - Pantnagar, Uttarakhand

There was an increasing trend in whitefly population (15.46 whitefly/3 leaves) during 51th standard week i.e. 3rd week of December when the maximum and minimum temperature was (22.5⁰C and 5⁰C), maximum and minimum relative humidity was (96.6% and 50.7%), rainfall was (0.0 mm), sunshine hours was (6.8 hrs.) and wind velocity was (2 km/hr.), followed by (11.13 whitefly/3 leaves) during 50th standard week and 10.70 whitefly/3 leaves during 52 standard week of 2018. Subsequently there shows a decreasing trend in whitefly population during 1st (9.05 whitefly/3 leaves) and 2nd (1.51 whitefly/3 leaves) standard week of January when the maximum and minimum temperature was (21.3⁰C, 21.6 and 6.1, 5.7⁰C), maximum and minimum relative humidity was (91%, 94% and 60%, 57%), rainfall was (0.0 mm and 0.0 mm), sunshine hours was (6 hrs. and 5.7 hrs.) and wind velocity was (0.00 and 0.00).

There is slight increase in whitefly population 3.41 whitefly/3 leaves during 3rd standard week when the maximum and minimum temperature was 21.7⁰C and 5.7⁰C, maximum and minimum relative humidity was 93% and 53%, rainfall was 0.0 mm, sunshine hours was 6.1 hrs. and wind velocity was 1.2km/hr. and reached its minimum (0.30 whitefly/3 leaves) in the 4th week of January.

The population ranged from 1.44 to 3.92 nymphs and adults per plant with seasonal mean of 2.80 whiteflies. It first appeared on the crop in the 3rd week of December with a mean population of 1.44 whiteflies. Thereafter the density of whitefly increased gradually with a peak of 3.92 whiteflies in the third week of December. The population showed a declining trend for a week then started increasing with second peak in the last week of January (3.84 flies/plant). The present findings are almost similar to those of Paul and **Konar (2005)** who reported that whitefly first appeared on the crop during first week of December with peak in last week of December. **Nag (2016)** recorded two peaks of whitefly during third week of December and January. **Rashid et al. (2013)** also recorded peak activity during third week of December. **Mathur et al. (2012)** reported peak activity of whitefly during January second week. On the contrary, **Oomen and Kumar (2004)** observed whitefly incidence from mid-July with peak in the first week of September. The findings are in support with **Lakra (2001)** who also recorded the buildup of white fly on 1st November planted potato crop in Haryana. **Mathur et al. (2012)** also reported that the incidence of whitefly (*Bemisia tabaci*) was maximum (9 whitefly/5 plant) during January (2nd SW) and lowest was recorded in March (12th SW). **Rashid et al. (2013)** also reported that the peak

population of whitefly (23.6 whitefly/5 leaves) was on the third week on December. Then there was a gradual decline in the population and reached its minimum during 8th standard week. **Dahatonde et al. (2014)** also reported that whitefly (*Bemisia tabaci* Gennadius) started from November (7.27 whiteflies/3 leaves) and reached to a peak level (25.73 whiteflies/3 leaves) during January.

4.4.2. Correlation between *Bemisia tabaci* (Gennadius) and weather parameters

The compiled data on population dynamics of whitefly in relation to weather parameters at VRC Pantnagar during 2018-19 presented in **Table 4.3.** showed non-significant positive correlation maximum relative humidity (0.455) sun-shine hrs. (0.439) whereas non-significant negative correlation with maximum temperature (-0.061) rainfall (-0.428) wind velocity (-0.243) There is a significant negative correlation between minimum temperature (0.557*)

4.4.3. Population dynamics of potato hopper (*Empoasca devastans*)

The compiled data on population dynamics of *Empoasca devastans* was studied on Kufri Surya in relation to weather parameters at VRC Pantnagar during 2018-19 presented in **Table 4.4.**

The initial appearance 0.31 hoppers/3 leaves was observed during 47th standard week i.e. 3th week of November. The population of the hopper gradually increased in the 48th standard week was 2.88 hoppers/3 leaves when the maximum and minimum temperature was 26.4⁰C and 10.7⁰C), maximum and minimum relative humidity was 94.6% and 60.6%, rainfall was 0.0 mm, sunshine hours was 6.2 hrs. and wind velocity was 1.8 km/hr. subsequently a decreasing trend is observed during 49th standard week (1.88 hoppers/3 leaves).

There was an increasing trend in hopper population (5.43 hoppers/3 leaves) during 50th standard week when the maximum and minimum temperature was (22.6⁰C and 6.6⁰C), maximum and minimum relative humidity was (94.6% and 60.4%), rainfall was (0.08 mm), sunshine hours was (6.3 hrs.) and wind velocity was (1.9 km/hr.). There was a decrease in population during followed by 51st standard week (3.47 hoppers/3 leaves) i.e. 3rd week of December. Subsequently there shows a sudden decreasing trend in hopper population during 1st (1.97 hoppers/3 leaves) and 2nd (1.25 hoppers/3 leaves) standard week of January. There is slight decrease in hopper population (0.34 hoppers/3 leaves) during 3rd standard week of 2019 and reached to nil (0.00 hoppers/3 leaves) in the

Table 4.4: Mean population of *Empoasca devastans* in relation to weather parameters in potato (2018-19) - Pantnagar, Uttarakhand

Month	Date	Standard week	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sun- Shine Hrs.	Wind velocity (km/hr.)	Mean
			Max.	Min.	07-12 am	14-12 pm				
November	16	46	26.5	11.8	93.3	63.1	0.0	6.5	2.3	0.00
November	23	47	26.3	10.5	93.4	54.3	0.0	7.7	1.8	0.31
November	30	48	26.4	10.7	94.6	60.6	0.0	6.4	1.9	2.88
December	07	49	23.8	7.8	92.6	61.0	0.0	6.2	1.8	1.88
December	15	50	22.6	6.6	94.6	60.4	0.8	6.3	1.9	5.43
December	23	51	22.5	5.0	96.6	50.7	0	6.8	2	3.47
December	30	52	20.3	2.7	97.1	51.9	0	6.7	2	3.51
January	06	1	21.3	6.1	91	60	0	6	0	1.97
January	13	2	21.6	5.7	94	57	0	5.7	0	1.25
January	20	3	21.7	5.7	93	53	0	6.1	1.2	0.34
January	27	4	20.5	8.6	88	50	14.2	3.8	4.3	0.00
February	04	5	20.9	7.0	93	63	0	6.1	1.6	0.00
February	11	6	21.1	9.1	95	66	15	4.7	3.4	0.00
Correlation			-0.019	-0.456	0.510	-0.141	-0.382	0.341	-0.207	

*Significant at p= 0.01 level; ** Significant at 0.05 level; Max-Maximum temperature; Min.- Minimum temperature; Mean- population of hopper (no. per leaf)

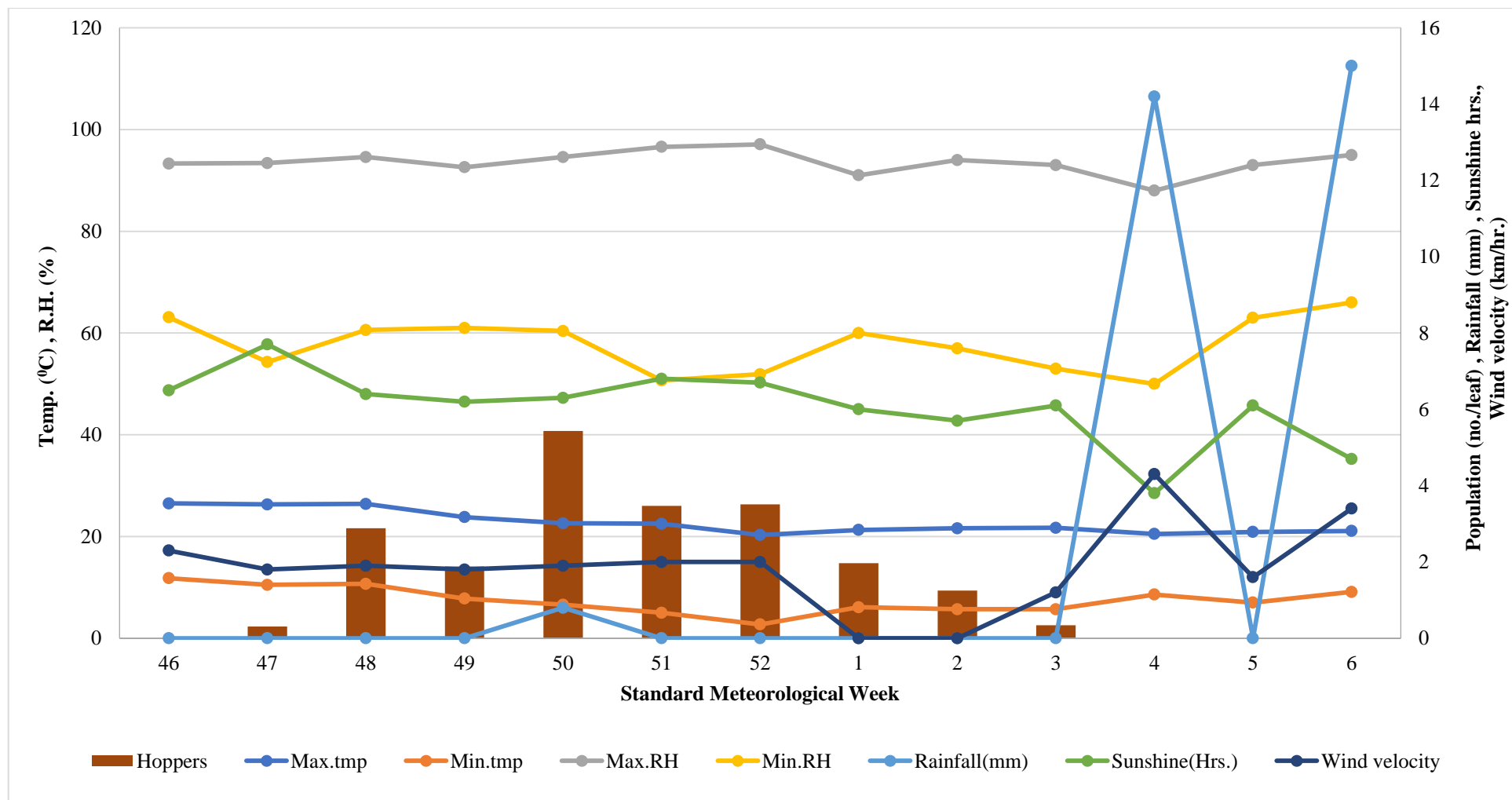


Fig. 4.3. Mean population of *Empoasca devastans* in relation to weather parameters in potato (2018-19) - Pantnagar, Uttarakhand

4th week of January when the maximum and minimum temperature was (20.5⁰C and 8.6⁰C), maximum and minimum relative humidity was (88% and 50%), rainfall was (14.20 mm), sunshine hours was (3.8 hrs.) and wind velocity was (4.3km/hr.).

The decrease in the population of *Empoasca devastans* in the 4st week of January was probably due to considerable rainfall (14.2 mm) which lead to large scale hopper mortality was nil due to washing off and drowning.

The leafhopper population ranged from 0.84 to 4.04 nymphs and adults per plant with seasonal mean of 2.26. Leaf hoppers first appeared on the crop in the 2nd week of December with the mean population 0.84 leafhopper per plant. Peak activity was recorded during the 3rd week of January (4.04 hoppers /plant) with a seasonal mean of 2.26 leaf hoppers per plant similar to the findings of **Nag (2016)** at Raipur. **Mathur et al. (2012)**, on the other hand, recorded maximum density of leafhopper during December last week. The findings are in support with **Dahatonde et al. (2014)** who reported that jassid started from November (3.20 jassids/3leaves) and reached to a peak level (22.46 jassids/3 leaves) during December.

4.4.3.1 Correlation between hopper, *Empoasca devastans* and weather parameters.

The compiled data on population dynamics of hopper in relation to weather parameters at VRC Pantnagar during 2018-19 presented in **Table 4.4.** showed non-significant positive correlation with and sunshine hours (0.341) minimum relative humidity (0.510) whereas non- significant negative correlation with maximum and minimum temperature (-0.019, -0.456) and wind velocity (-0.207) and rainfall (-0.382) maximum relative humidity (-0.141).

4.4.4 Population dynamics of thrips (*Thrips palmi*)

The compiled data on population dynamics of *T. palmi* was studied on Kufri Surya in relation to weather parameters at VRC Pantnagar during 2018-19 presented in **Table 4.5.** The initial appearance thrips (0.16 thrips /3 leaves) was observed during 51th standard week *i.e.* 3th week of December. The population of the thrips increased in the 52th standard week (0.73/3 leaves) when the maximum and minimum temperature was 20.3⁰C 2.7⁰C, maximum and minimum relative humidity was 97.1% and 51.9%, rainfall was 0.00 mm, sunshine hours was 6.7 hrs. and wind velocity was 2 km/hr.

Table 4.5: Mean population of *Thrips palmi* in relation to weather parameters in potato (2018-19) - Pantnagar, Uttarakhand

Month	Date	Standard week	Temperature (⁰ C)		Relative Humidity (%)		Rainfall (mm)	Sun- Shine Hrs.	Wind velocity (km/hr.)	Mean
			Max.	Min.	07-12 am	14-12 pm				
November	16	46	26.5	11.8	93.3	63.1	0.0	6.5	2.3	0.00
November	23	47	26.3	10.5	93.4	54.3	0.0	7.7	1.8	0.00
November	30	48	26.4	10.7	94.6	60.6	0.0	6.4	1.9	0.00
December	07	49	23.8	7.8	92.6	61.0	0.0	6.2	1.8	0.00
December	15	50	22.6	6.6	94.6	60.4	0.8	6.3	1.9	0.00
December	23	51	22.5	5.0	96.6	50.7	0	6.8	2	0.16
December	30	52	20.3	2.7	97.1	51.9	0	6.7	2	0.73
January	06	1	21.3	6.1	91	60	0	6	0	4.58
January	13	2	21.6	5.7	94	57	0	5.7	0	11.14
January	20	3	21.7	5.7	93	53	0	6.1	1.2	14.65
January	27	4	20.5	8.6	88	50	14.2	3.8	4.3	18.80
February	04	5	20.9	7.0	93	63	0	6.1	1.6	7.33
February	11	6	21.1	9.1	95	66	15	4.7	3.4	2.20
Correlation			-0.536	-0.176	-0.648*	-0.399	0.384	-0.661*	0.094	

*Significant at p= 0.01 level; ** Significant at p= 0.05 level; Max-Maximum temperature; Min.- Minimum temperature; Mean- population of thrips (no. per leaf)

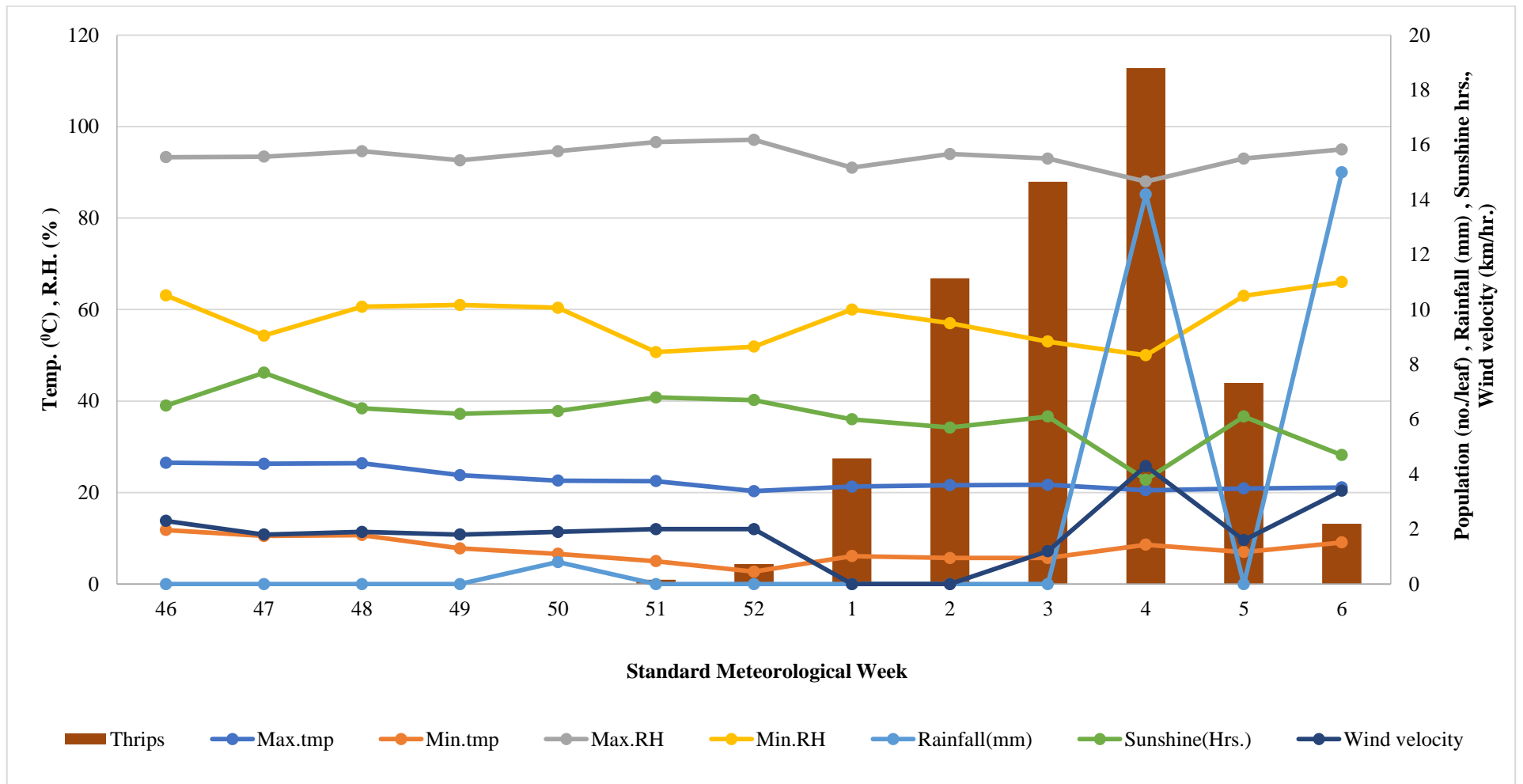


Fig. 4.4. Mean population of *Thrips Palmi* in relation to weather parameters in Potato (2018-19) - Pantnagar, Uttarakhand

There was an increasing trend in thrips population (4.58 thrips/3 leaves) during 1th January standard week when the maximum and minimum temperature was 21.3^oC and 6.1^oC, maximum and minimum relative humidity was 91% and 60%, rainfall was 0.00 mm, sunshine hours was 6 hrs. and wind velocity was 0.00. There was an gradually increase in population during 2st (11.14 thrips /3 leaves), 3nd (14.65 thrips /3 leaves), 4nd (18.80 thrips /3 leaves) standard week of January and slight decrease in 5th and 6th (7.33 thrips /3 leaves), (2.20 thrips /3 leaves) respectively during 2019.

The thrips population ranged from 1.16 to 8.20 nymphs and adults per plant with seasonal mean of 3.99 thrips. It first appeared on the crop in the 3rd week of December with a mean population of 1.16 thrips. Thereafter, the density of thrips increased gradually with a peak of 8.20 thrips /plant in the last week of January whereas, **Pathipati et al. (2014)** observed peak incidence of thrips during last week of December and **Rashid et al. (2013)** during last week of February. **Patel et al. (2009)** recorded thrips incidence from first week of September with peak in November and March. **Nag (2016)** observed peak activity of thrips during third week of January.

4.4.4.1 Correlation between thrips (*Thrips palmi*) and weather parameters

The compiled data on population dynamics of thrips in relation to weather parameters at VRC Pantnagar during 2018-19 presented in **Table 4.5.** showed non-significant positive correlation rainfall (0.384) and wind velocity (0.094) whereas non-significant negative correlation with maximum and minimum temperature (-0.536, -0.176) maximum relative humidity (-0.399) and significant negative correlation between minimum relative humidity (-0.648*).

4.5. Effect of weather parameters on natural enemies population.

4.5.1 Ladybird beetles (*Coccinella septumpunctata*)

Maximum Temperature

The correlation coefficient between number of *Coccinella septumpunctata* per plant and maximum temperature was worked out. The two variables had negative trend with “r” value (-) 0.439. The peak activity of *Coccinella septumpunctata* (2.58) was recorded in the 3rd week of January which was associated with 21.7^oC max. temperature.

Minimum Temperature

The association between number of *Coccinella septumpunctata* and min. temperature was worked out. The two variables had negative trend with “r” value (-) 0.490. The peak density of ladybird beetle was recorded in the 3rd week of January with 5.7°C minimum temperature.

Morning Relative Humidity

The correlation coefficient between number of *Coccinella septumpunctata* per plant and mean relative humidity was worked out. There was a negative trend with “r” value (-) 0.132 at 5% level. The peak density of ladybird beetle was recorded in the 3rd week of January with 93% mean morning (07-12 am) relative humidity.

Evening Relative Humidity

The correlation coefficient between number of *Coccinella septumpunctata* per plant and mean relative humidity of evening had a negative trend “r” = (-) 0.318) at 5% level. The peak density of ladybird beetle, *Coccinella septumpunctata* was recorded in the 3rd week of January with 53% mean evening (14-12pm) relative humidity.

Wind velocity

The correlation coefficient between number of ladybird beetle, *Coccinella septumpunctata* per plant and wind velocity (km/h) had negative trend “r” = (-) 0.516. The peak density of ladybird beetle, *Coccinella septumpunctata* was recorded in the third 3rd week of January with 1.2 km/h mean wind velocity.

Sunshine hours

The correlation coefficient between number of ladybird beetles, *Coccinella septumpunctata* per plant and sunshine hours was worked out and had a negative trend with “r” = (-) 1.77. The peak density of ladybird beetle, *Coccinella septumpunctata* was recorded in the 3rd week of January with 6.1 lux mean sunshine hours. In the present studies the population of ladybird, *Coccinella septumpunctata* was not influenced by any weather parameters.

Table 4.6: Mean population of natural enemies and its correlation with weather parameters in potato (2018-19) - Pantnagar, Uttarakhand

Month	Date	Standard week	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Sun-Shine Hrs.	WV (km/hr.)	Natural Enemies (no. per plant)		
			Max.	Min.	07-12 am	14-12 pm				<i>Coccinellid beetles</i>	Spiders	Staphylinid beetle
November	16	46	26.5	11.8	93.3	63.1	0.0	6.5	2.3	0	0.00	0
November	23	47	26.3	10.5	93.4	54.3	0.0	7.7	1.8	0	0.00	0
November	30	48	26.4	10.7	94.6	60.6	0.0	6.4	1.9	0.2	0.30	0.22
December	07	49	23.8	7.8	92.6	61.0	0.0	6.2	1.8	0.07	0.56	0.62
December	15	50	22.6	6.6	94.6	60.4	0.8	6.3	1.9	0.23	0.12	0.29
December	23	51	22.5	5.0	96.6	50.7	0	6.8	2	0.12	0.44	0.41
December	30	52	20.3	2.7	97.1	51.9	0	6.7	2	0.76	0.17	0.31
January	06	1	21.3	6.1	91	60	0	6	0	1.14	0.21	0.05
January	13	2	21.6	5.7	94	57	0	5.7	0	2.04	0.16	0.36
January	20	3	21.7	5.7	93	53	0	6.1	1.2	2.58	0.28	0.18
January	27	4	20.5	8.6	88	50	14.2	3.8	4.3	0.57	0.31	0.41
February	04	5	20.9	7.0	93	63	0	6.1	1.6	0.29	0.37	0.43
February	11	6	21.1	9.1	95	66	15	4.7	3.4	0.2	0.39	0.23
Correlation	Lady bird beetle		-0.439	-0.490	-0.132	-0.318	-0.034	-0.177	-0.516			
	Spider		-0.352	-0.223	-0.029	0.058	0.249	-0.340	0.196			
	Staphylinid beetle		-0.425	-0.388	-0.008	-0.123	0.117	-0.318	0.173			

*Significant at p= 0.01 level; ** Significant at p= 0.05 level; Max-Maximum temperature; Min. - Minimum temperature; WV-Wind Velocity

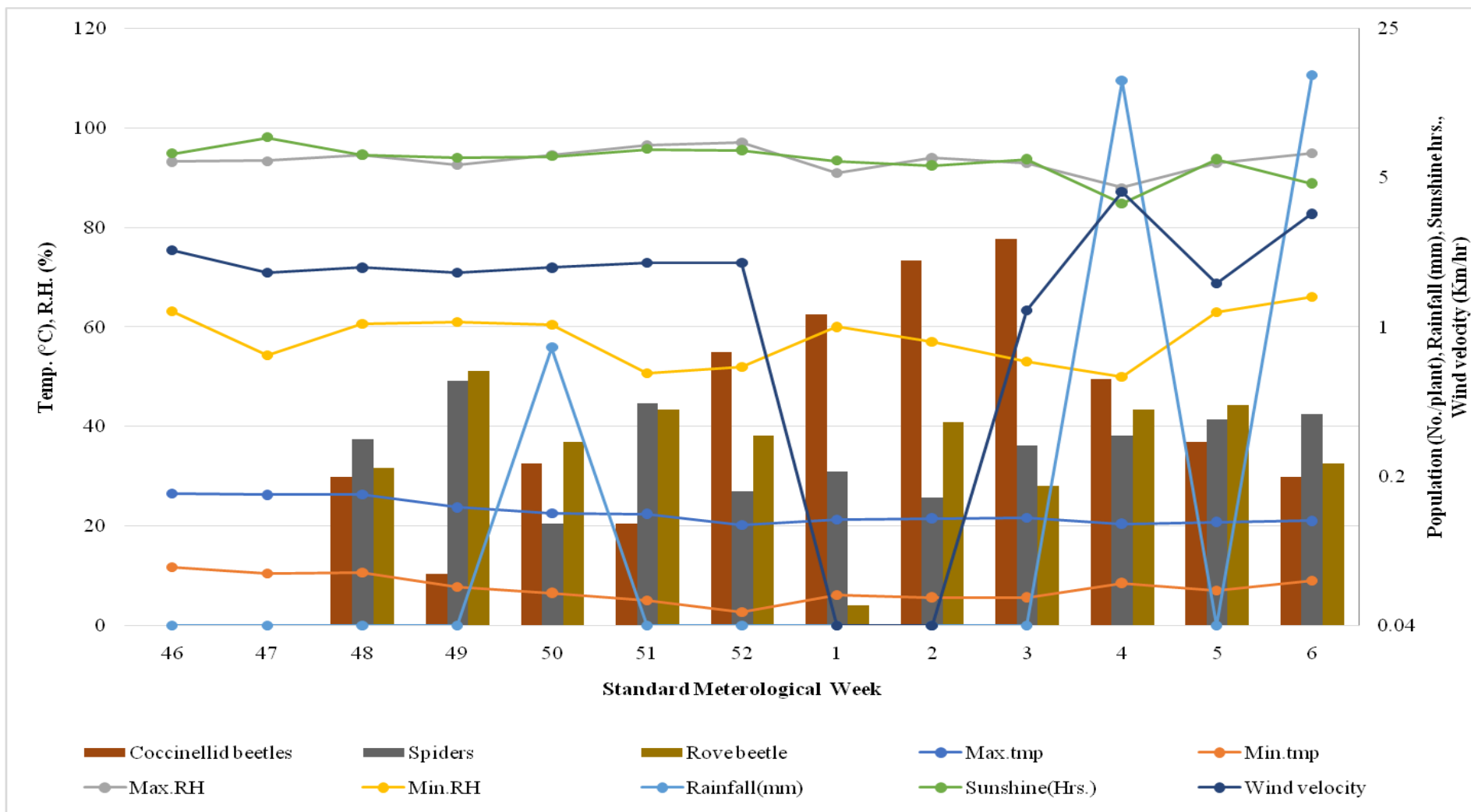


Fig 4.5. Mean population of natural enemies and its correlation with weather parameters in potato (2018-19)

4.5.2 Spider (*Oxyopes satticus*)

Maximum Temperature

The correlation coefficient between number of spiders, *Oxyopes satticus* per plant and maximum temperature was worked out. The two variables had negative trend “r” = (-) 0.352. The peak activity of spider was recorded in the 1st week of December which was associated with 23.8°C maximum temperature.

Minimum Temperature

The association between number of spiders, *Oxyopes satticus* and minimum temperature was worked out. The two variables had negative trend with “r” value (-) 0.223. The peak density of spider was recorded in the 1st week of December with 7.8°C minimum temperature.

Morning Relative Humidity

The correlation coefficient between number of spiders, *Oxyopes satticus* per plant and mean relative humidity of morning was found to be negative correlated (“r”= (-) 0.029) at 5% level. The peak density of spider, *Tetranychus urticae* was recorded in the 1st week of December with 92.6% mean morning relative humidity.

Evening Relative Humidity

The correlation coefficient between number of spiders per plant and mean relative humidity of evening had positive trend (“r”= 0.058). The peak density of spider, *Oxyopes satticus* was recorded in the 1st week of December with 61.0% mean evening relative humidity.

Wind velocity

The correlation coefficient between number of spiders, *Oxyopes satticus* per plant and wind velocity (km/h) had positive correlation (“r”=0.249) at 5% level. The peak density of spider was recorded in the 1st week of December with 1.8 kmph mean wind velocity.

Sunshine hours

The correlation coefficient between number of spiders, *Oxyopes satticus* per plant and sunshine hours was worked out and had negative correlation with “r” value (“r” = (-) 0.340). The peak density of spider, *Oxyopes satticus* was recorded in the 1st week of December with 6.2 lux mean sunshine hours.

4.5.3. Rove beetles (*Paederus dermatitis*)

Maximum Temperature

The correlation coefficient between number of rove beetles per plant and maximum temperature was worked out. There was a negative trend (“r”= (-) 0.425). The peak activity of rove beetle was recorded in the 1st week of December which was associated with 23.8⁰C maximum temperature.

Minimum Temperature

The association between number of rove beetles per plant and minimum temperature was worked out. The two variables had negative trend with “r” value (-) 0.388. The peak density of rove beetle was recorded in the 1st week of December with 7.8⁰C minimum temperature.

Morning Relative Humidity

The correlation coefficient between number of rove beetles per plant and mean relative humidity was worked out. There was a negative trend with “r” value (“r” = (-) 0.008). The peak density of Staphylinid beetle was recorded in the 1st week of December with 92.6% mean morning relative humidity.

Evening Relative Humidity

The correlation coefficient between number of rove beetle per plant and mean relative humidity of evening had negative trend (“r” = (-) 0.123). The peak density of rove beetle was recorded in 1st week of December with 61.0% mean evening relative humidity.

Wind velocity

The correlation coefficient between number of rove beetles per plant and wind velocity (km/h) had positive trend (“r” = 0.173) at 5% level. The peak density of rove beetle was recorded in 1st week of December with 1.8 km/h mean wind velocity.

Sunshine hours

The correlation coefficient between number of rove beetle per plant and sunshine hours was worked out and had negative trend with “r” value - (-) 0.22). The peak density of rove beetle was recorded in 1st week of December with 6.2 lux means sunshine hours.

Tank and Korat (2007) the present results are partially similar to the findings. They recorded negative association of ladybird beetle with minimum temperature, bright sunshine hours and wind speed, while positive association for relative humidity and vapour pressure recorded during morning and evening hours. However, in none of the cases, it was significant. **Ghosh et al. (2013)** reported that Abiotic conditions such as minimum temperature, temperature gradient, maximum relative humidity and average relative humidity had significant positive influence on *C. septempunctata* population. In case of minimum relative humidity and sunshine hours, a negative influence was observed. In addition, other factors such as rainfall imparted in significant positive effect on population development.

Sarwar (2013) reported that meteorological conditions were more favorable for development of insect pests and natural enemies due to the combination of different abiotic factors. Similar result was also obtained by **Bijur and Verma (1996)** that populations of predatory coccinellids and spiders were negatively correlated with maximum temperature. Multiple linear regression models indicated a significant cumulative effect of abiotic factors on *Chromatomyia horticola*, *H. armigera* and coccinellid predators.

Sathe and Margaj (2001) reported that the predator population can be influenced by abiotic factors such as weather (temperature, humidity, rainfall and light, etc.). The efficiency of predator species is dependent on prey density, predator density, characteristic of the prey and predator and environment. Similar results were observed in the present studies. **Shukla (2014)** showed significant negative correlation of Coccinellids with maximum temperature and maximum relative humidity, while there was no significant relationship with minimum temperature, minimum relative humidity, and rainfall. **Silva et al. (2015)** observed that diurnal temperature affects the night hourly dispersal of staphylinid (rove) beetles as well as their distribution pattern during the entire period of study. The true environmental conditions responsible for Paederus beetles, seasonal pattern and daily night dispersal in northeastern Brazil were the annual moisture and draught cycles and the diurnal maximum temperatures, respectively.

4.6. Seasonal fluctuation of predatory fauna of potato pests

Potato is mainly attacked by aphid (*Aphis gossypii*, *Myzus persicae*), whitefly (*Bemisia tabaci*), thrips (*Thrips palmi*) and Leafhopper (*Amrasca bigutulla bigutulla*, *Empoasca fabae*, *Empoasca devastans*) at different growth stages of the crop. To assess the potential of biological control of these insects on potato, the study was undertaken during *rabi*, 2018-2019. It revealed the following predatory fauna on these insects.

4.6.1 Ladybird beetles, *Coccinella septumpunctata* (Coleoptera: Coccinellidae)

The *Coccinella* spp. ranged from 0 to 2.58 grub and adult per plant with seasonal mean of 0.63 ladybird beetles. Five different species of ladybird beetles seen on potato field were recorded as the major bioagents of the sucking pests. They first appeared on the crop in the last week of November with 0.30 grub and adult per plant. They were observed feeding on nymphs and adults of aphid (*Myzus persicae*, *Aphis gossypii*), leaf hopper (*Empoasca devastans*, *Amrasca bigutulla bigutulla*), thrips (*Thrips palmi*) and whiteflies (*Bemisia tabaci*). Their activity continued till the last 2nd week of February with 0.2 grub and adult per plant. Nag (2016) reported peak activity during third week of January.

4.6.2 Staphylinidae beetle, *Paederus dermatitis* (Coleoptera: Staphylinidae)

The staphylinid beetle ranged from 0 to 0.62 adult per plant with seasonal mean of 0.27. Staphylinid beetle was recorded as one of the major bio-agents of the sucking pests. They first appeared on the crop in the last week of November with 0.24 grub and adult per plant. They were observed feeding on nymphs and adults of aphid (*Myzus persicae*, *Aphis gossypii*), leafhopper (*Empoasca devastans*, *Amrasca bigutulla bigutulla*), thrips (*Thrips palmi*) and whiteflies (*Bemisia tabaci*). Their activity continued till the last 2nd week of February with 0.23 grub and adult per plant. Nag (2016), on the other hand, recorded peak density of staphylinid beetle during third week of December and January.

4.6.3 Spiders, *Oxyopes satticus* (Araneae: Hypochilidae)

The spiders first appeared on the crop in the last 4th week of November with mean population of 0.25 spiders per plant. Nag (2016), reported peak activity of spiders during first and third week of December and January. It coincided with the

appearance of host insects on the crop. They were active throughout the growth period of the crop with peak of 0.56 spider per plant during 1st week of December. Their population ranged from 0 to 0.56 spiders with a seasonal mean of 0.25 spiders per plant. **Saljoqi (2009)** reported highest density of natural enemies during third week of March on potato, whereas, in the present investigation peak density of ladybird beetle, staphylinid beetle and spiders was recorded during last week December to last week January. The peak activity of all the predators was observed during last week December to last week January which coincided with the peak activity of most of the sucking pests.

4.7. Correlation of natural enemies with their insect pests of potato

In the present studies, three predators namely Ladybird beetles, *Coccinella septumpunctata* spiders, *Oxyopes saticus* and Staphylinid beetle, *Paederus dermatitis* were observed as major bio-agents of whiteflies (*Bemisia tabaci*), aphid (*Aphis gossypii*, *Myzus persicae*), thrips (*Thrips palmi*), and leafhopper (*Amrasca bigutulla bigutulla*, *Empoasca devastans*, *Empoasca fabae*). To observe the effect of predatory population on the activity of the insect pests, the population of predators was co-related with the population of major sucking pests. There was positive trend in the population of aphid with Staphylinid beetle, aphid and spiders having “r” value of 0.226 and 0.099, respectively at 5 percent level of significance. However, there existed a significantly positive correlation between aphid and ladybird beetles with “r” value of 0.714** at the same level of significance. The regression equation for the two variables was $y = 0.129x + 0.233$, $R^2 = 0.509$ (**Fig 4.6.1**). **Moschetti (2003)** reported that ladybird beetles (*Coccinella septumpunctata*) are attracted to and feed heavily on aphids (*Aphis gossypii*, *Myzus persicae*). **Saljoqi (2009)** conducted an experiment to determine the population dynamics of Aphid (*Myzus persicae*) and its associated natural enemies, ladybird beetles (*Coccinella septempunctata* (L), *Episyrphusbalt eatus* (De Geer), *Chrysoperla carnea* (Stephens), and *Aphidiusmatri cariae*) holiday and percent parasitism of the aphid (*Myzus persicae*, *Aphis gossypii*) in the spring potato cultivar kurodo at Peshawar during 2006. The results showed that Aphid (*Myzus persicae*, *Aphis gossypii*) was consistently observed at different densities at different times on potato throughout the growing season. In potatoes, aphids (*Myzus persicae*, *Aphis gossypii*) rarely maximum reach populations which

lower potato yields by their feeding alone due to natural enemy complex including ladybird beetle (coccinellid spp.), predatory bugs in genera *Orius*, *Nabis* and *Geocoris*, lacewings, spiders, syrphid fly larvae, predatory gall midge larvae (Cecidomyiidae) and aphid specific parasitoids **Giordanengo et al. 2013**). **Neergude et al. (2014)** conducted a roving survey in *Kharif* season from seedling stage till harvest of the crop at Bijapur. The population of thrips was very low during seedling stage; it gradually increased during vegetative stage of the crop and reached a peak occurrence during physiological maturity stage. The population of both the predators, spiders (*Oxyopes saticus*) and ladybird beetles was low during seedling stage of the crop while it slightly increased during potato vegetative stage of the crop and reached a peak occurrence during physiological maturity stage. The population of both the predators, spiders (*Oxyopes saticus*) and ladybird beetles was low during seedling stage of the crop while it slightly increased during vegetative stage of the crop.

There was a positive trend between the population of thrips (*Thrips palmi*) and rove beetle and thrips and spider with “r” value of 0.172 and 0.098, respectively at 5 per cent level of significance. While there was significant positive correlation between thrips (*Thrips palmi*) and lady bird beetle (*Coccinella septumpunctata*) with “r” value of 0.661* at the same level of significance. The regression equation worked out for the two variables was $y = 0.084x + 0.244$, $R^2 = 0.437$ (**Fig. 4.6.2**).

While there was no significant relation between leafhopper and staphylinid beetle ($r = 0.209$) at the same level of significance. There was a positive trend between whitefly and all the natural enemies at 5 percent level of significance.

The “r” values for staphylinid beetle, spider and ladybird beetle were 0.36, 0.35 and 0.65, respectively. **Williamson (1998)** observed predation of whitefly (*Bemisia tabaci*) by coccinellid (*Coccinella spp.*) and staphylinid beetles and that of leafhopper by coccinellids beetles and spider (*Oxyopes saticus*). **Moschetti (2003)** reported that several species of ladybird beetles (*Coccinella spp.*) feed heavily on aphid, (*Myzus persicae*, *Aphis gossypii*) and eggs of Colorado beetles on potato. **Shivalingaswamy et al. (2002)** reported that rove beetle, Paederus species, voraciously feed on the soft-bodied insects like leafhoppers in okra ecosystem.

Table 4.7: Correlation coefficients - sucking pests vis-vis coccinellid, spider and staphylinid beetle in potato (2018-19)- Pantnagar, Uttarakhand

Population of insect pests and their natural enemies / plant								
Date		Aphid	White fly	Leaf hopper	Thrips	Staphylinid beetle	Spider	Lady bird beetle
16-Nov		0.00	0.00	0.00	0.00	0	0.00	0
23-Nov		0.84	3.25	0.31	0.00	0	0.00	0
30-Nov		1.62	5.27	2.88	0.00	0.22	0.30	0.2
07-Dec		3.72	9.40	1.88	0.00	0.62	0.56	0.07
15-Dec		8.55	11.13	5.43	0.00	0.29	0.12	0.23
23-Dec		10.54	15.46	3.47	0.16	0.41	0.44	0.12
30-Dec		11.62	10.70	3.51	0.73	0.31	0.17	0.76
06-Jan		10.99	9.05	1.97	4.58	0.05	0.21	1.14
13-Jan		11.85	1.51	1.25	11.14	0.36	0.16	2.04
20-Jan		12.13	3.41	0.34	14.65	0.18	0.28	2.58
27-Jan		6.43	0.30	0.00	18.80	0.41	0.31	0.57
04-Feb		5.11	0.00	0.00	7.33	0.43	0.37	0.29
11-Feb		3.27	0.00	0.00	2.20	0.23	0.39	0.2
	Staphylinidbeetle	0.226	0.247	0.209	0.172	-	-	-
Correlation Coefficient	Spider	0.099	0.220	0.012	0.098	-	-	-
	Lady birdbeetle	0.714**	-0.140	-0.147	0.661*	-	-	-

*Significant at p= 0.01 level; ** Significant at p= 0.05level

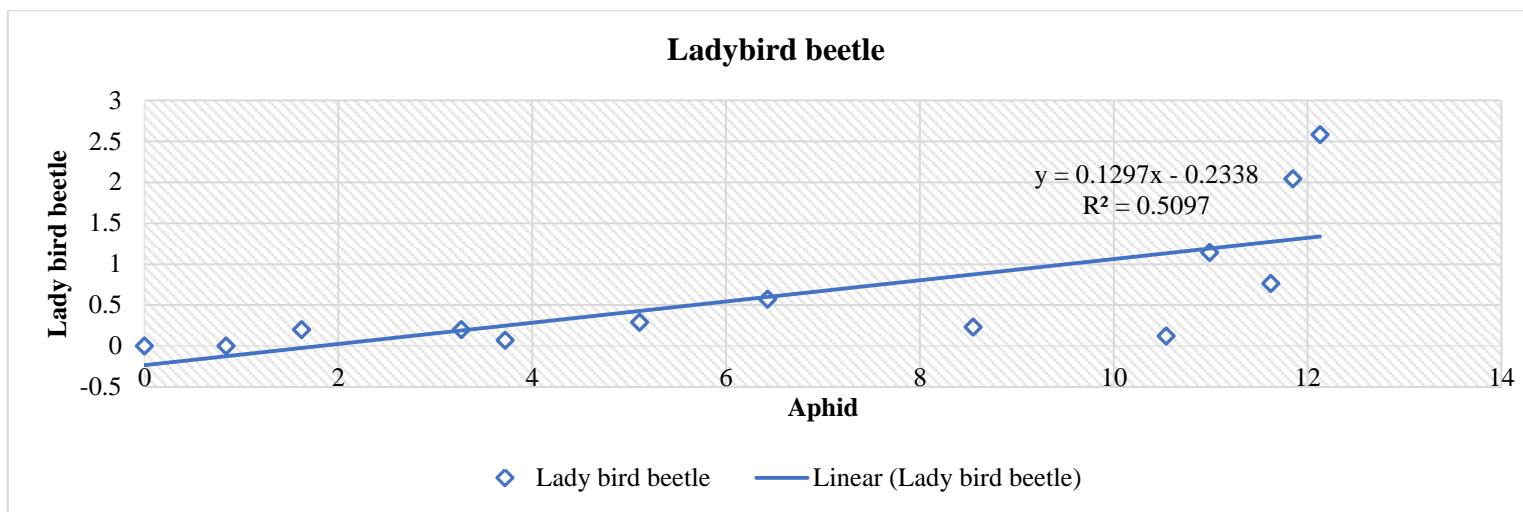


Fig 4.6.1Regression line of Aphid per plant on ladybird beetle

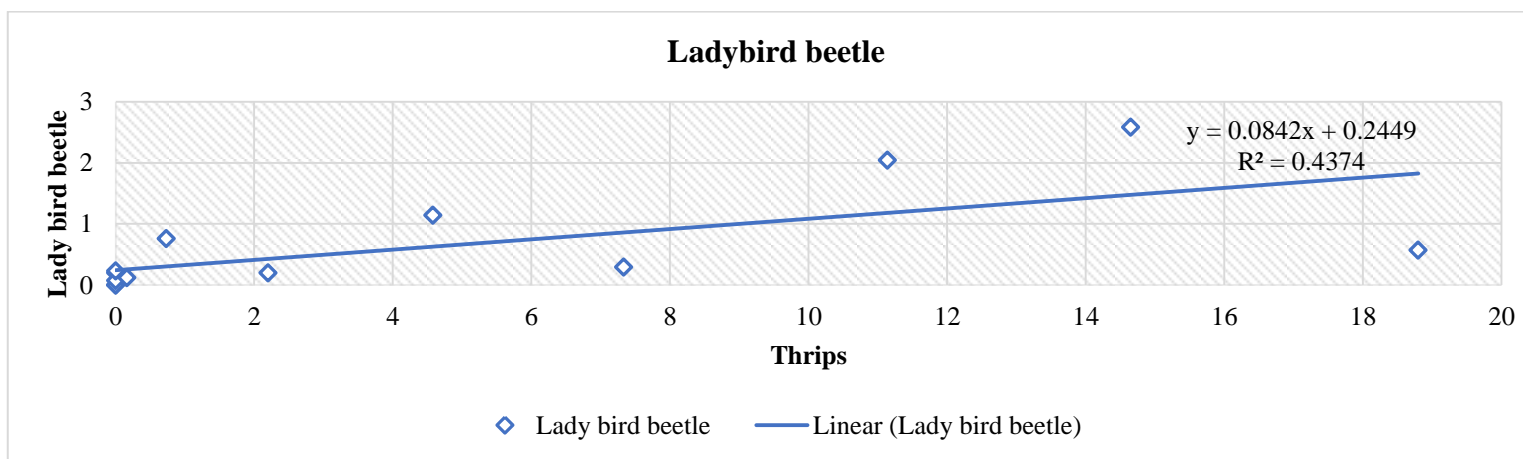


Fig 4.6.2Regression line of Thrips per plant on ladybird beetle

Fig. 4.6. Regression of population dynamics of natural enemies with sucking insect pest of potato during rabi season 2018-19

4.8. Experiment No - 2

Comparison of imidacloprid and flonicamid against insect pests of potato.

The effect of imidacloprid and flonicamid were studied against various insect pest of potato (Table 4.8 – 4.11)

4.8.1 Efficacy of imidacloprid and flonicamid against whitefly.

The periodical data on population of whitefly (*Bemisia tabaci*) were recorded on potato one day before and 2nd, 4th and 6th days after each application in cropping season 2018-19 and is presented below:

Perusal of Table 4.8 revealed that before first spray the mean population of whitefly varied from 14.35 to 16.70 /3 leaves, no significant difference was observed amongst treatments.

After two days of application minimum number of whitefly population, 2.99 whitefly/3 leaves has been observed in T₅ (flonicamid 50 WG @ 3g /10 lits + repeat at 15 days) followed by 3.61 whitefly /3 leaves in T₄ (flonicamid 50 WG @ 3g /10 lits), 3.82 whitefly/3 leaves in T₂ (imidacloprid 17.8 SL @3ml/10lits) and 5.39 whitefly /3 leaves in T₃ (imidacloprid 17.8 SL @3ml/10 lits + repeat at 15 days), however whitefly population in all treatments was significant less than untreated control (15.63 whitefly /3 leaves).

After 4th days of application minimum number of whitefly population, 2.95 whitefly/3 leaves has been observed in T₅ (flonicamid 50 WG@3ml/10lits + repeat at 15 days) followed by 2.97 whitefly/3 leaves in T₂ (Imidacloprid 17.8 SL@3ml/10 lits), 3.42 whitefly/3 leaves in T₃ (flonicamid 50 WG@3ml/10lits) and 4.25 whitefly/3 leaves in T₃ (imidacloprid 17.8 SL@3ml/10 lits + repeat 15days), however whitefly population in all the treatments was significantly less than unsprayed control (16.58 whitefly/3 leaves). Same trend has been observed on 6th days of spray.

On the basis of overall mean population, T₅ was most effective treatment followed by T₄, T₂, and T₃

Perusal of Table 4.8 revealed that before 2nd spray the mean population of whitefly varied from 14.24 to 15.73 /leaves, no significant difference was observed amongst treatments.

Table 4.8: Efficacy of flonicamid and imidacloprid foliar spray against whitefly (2018-19)

Treat. No.	Treatments	Dose	Per leaf population of whitefly											
			Days after first Spray						Days after second spray					
			PTC	2	4	6	Mean	%ROC	PTC	2	4	6	Mean	%ROC
T1	Control	-	14.35 (3.82)	15.63 (4.00)	16.58 (4.12)	16.41 (4.14)	16.21	-	14.24 (3.82)	16.40 (4.10)	16.78 (4.14)	16.41 (4.10)	16.53	-
T2	Imidacloprid17.8SL	3ml/10lits	16.7 (4.13)	3.82 (2.07)	2.97 (1.81)	4.24 (2.12)	3.67	77.30	16.23 (4.07)	4.02 (2.12)	3.17 (1.87)	4.24 (2.15)	3.81	76.93
T3	Imidacloprid 17.8SL + repeat at 15 days	3ml/10lits	15.32 (3.96)	5.39 (2.38)	4.25 (2.17)	5.52 (2.44)	5.05	68.79	15.00 (3.92)	2.19 (1.52)	2.45 (1.63)	2.92 (1.70)	2.52	84.72
T4	Flonicamid 50 WG	3gm /10 lits	15.99 (4.03)	3.61 (1.98)	3.42 (1.95)	3.77 (2.05)	3.60	77.75	15.56 (3.99)	4.01 (2.14)	3.82 (2.07)	3.97 (2.10)	3.93	76.16
T5	Flonicamid 50 WG + repeat at 15 days	3gm /10 lits	16.10 (4.02)	2.99 (1.85)	2.95 (1.83)	3.21 (1.92)	3.05	81.15	15.73 (3.98)	1.99 (1.47)	1.75 (1.39)	2.41 (1.17)	2.05	87.56
	SE(m)±		.202	.166	.161	.132			.179	.215	1.888	.213		
	CD @ 0.5 %		.608	.498	.485	.398			.538	.646	.556	.639		
	F value		ns	**	**	**			ns	**	**	**		
PTC:Pre-treatment, H: Hours, ROC:Reduction over control														

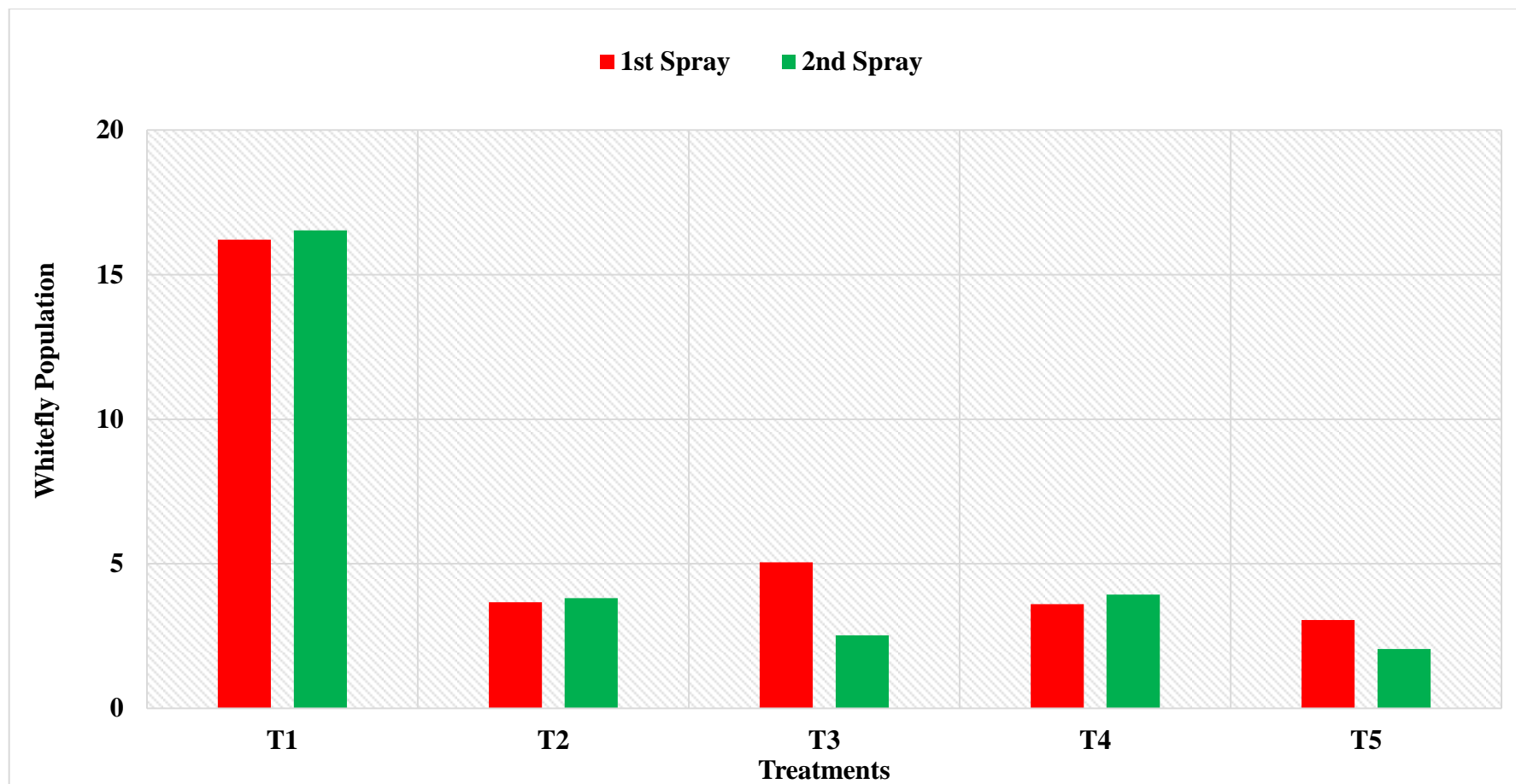


Fig 4.7. Efficacy of flonicamid and imidacloprid foliar spray against whitefly (2018-19)

After two days of application minimum number of whitefly population 1.99 Whitefly/3 leaves has been observed in T₅ (flonicamid 50 WG@3ml/10lits + repeat at 15 days) followed by 2.19 whitefly/3 leaves in T₃ (imidacloprid 17.8 SL @ 3ml/10 lits + repeat 15days), 4.01 whitefly/3 leaves in T₄ (flonicamid 50 WG @3ml/10lits) and 4.02 whitefly/3 leaves in (imidacloprid 17.8SL@3ml/10 lits), however *Bemisia tabaci* population in all the treatments was significantly less than untreated control (16.40 whitefly/3 leaves).

After 4th days of application minimum number of whitefly population 1.75 whitefly/3 leaves has been observed in T₅ (flonicamid 50 WG@3ml/10lits + repeat at 15 days) followed by 2.45 whitefly/3 leaves in T₃ (imidacloprid 17.8 SL@3ml/10 lits + repeat 15days), 3.17 whitefly/3 leaves in T₂ (imidacloprid 17.8 SL@3ml/10 lits) and 3.82 whitefly/3 leaves in T₄ (flonicamid 50 WG@3ml/10lits), However *Bemisia tabaci* population in all the treatments was significantly less than untreated control (16.78 whitefly/3leaves). Same trend has been observed on after 6th days of first spray.

On the basis of overall mean population, T₅ was most effective treatment followed by T₃, T₄, and T₂.

It was concluded that treatment T₅ of flonicamid 50 WG@3ml/10lits + repeat at 15 days were the promising treatments as they recorded minimum population after 2nd spray, followed by other treatments and untreated check.

Flonicamid also reduced the population of the whitefly by >85% when compared to untreated controls after three rounds of foliar application at an interval of 10 days. **Kodandaram et al. (2017)** flonicamid caused significantly maximum mortality of whitefly. **Ghelani et al. (2014)** also stated that after 7 and 15days of application, flonicamid at 0.02% caused 71.5 and 65.4% mortality of whitefly, **Roditakis et al. (2014)**, who also reported that flonicamid at the highest registered label rate, i.e., 125 mg caused 95% mortality of the sweet potato whitefly 10 days after the treatment, The cumulative efficacy of different insecticides against whiteflies at seven days of four sprays showed that flonicamid 10 WG (1.78/3 leaves/plant), diafenthiuron 50 WP (2.05/3 leaves/plant) All the insecticides tested were superior to untreated check by recording lower population of sucking pests. Among the insecticides tested, flonicamid10 WG was found to be effective against all sucking pests.

4.8.2. Efficacy of imidacloprid and flonicamid against aphid.

The periodical data on population of aphid (*Myzus persicae* Sulz.) were recorded on potato one day before and 2nd, 4th and 6th days after each application in cropping season 2018-19 and is presented below:

Perusal of table **Table 4.9** indicated that before first spray the mean population of aphid varied from 15.28 to 19.42 aphid /3 leaves, no significant difference was observed amongst treatments.

After two days of application minimum number of aphid population, 3.50 aphids/3 leaves has been observed in T₅ (flonicamid 50 WG @ g/10 lits + repeat at 15 days) followed by 3.79 aphids/3 leaves in T₄ (flonicamid 50 WG @3gm/lits), 3.88 aphids/3 leaves in T₂ (imidacloprid 17.8 SL@3ml/10lits) and 4.25 aphids/3 leaves in T₃ (Imidacloprid 17.8 SL@3ml/10lits + repeat at 15 days), however *Myzus persicae* population in all the treatments was significantly less than untreated control (20.17 aphids/3 leaves).

After 4th days of application minimum number of aphid population, 2.80 aphids/3 leaves has been observed in T₂ (imidacloprid 17.8 SL@3ml/10lits) followed by 3.34 aphids/3 leaves in T₄ (flonicamid50 WG @3gm/lits), 3.34 aphids/3 leaves in T₅ (flonicamid 50 WG @ g/10 lits + repeat at 15 days), and 3.41 aphids/3 leaves in T₄ (imidacloprid17.8 SL@3ml/10lits + repeat at 15 days), however *Myzus persicae* population in all the treatments was significantly less than untreated control (20.70 aphids/3leaves). Same trend has been observed on 6th day of spray.

On the basis of overall mean population, T₂ was most effective treatment followed by T₅, T₃, and T₂.

A perusal of **table 4.9** indicated that before 2nd spray the mean population of *Aphid* varied from 14.95 to 18.60 /3 leaves no significant difference was observed amongst treatments.

After 2 days of application minimum number of whitefly population was minimum 1.59 aphids/3 leaves has been observed in T₅ (flonicamid 50 WG @g/10 lits + repeat at 15 days) followed by 2.05 aphids/3 leaves in T₃ (imidacloprid 17.8 SL@3ml/10lits + repeat at 15 days), 3.59 aphids/3 leaves in T₄ (flonicamid 50 WG @g/10 lits) and 4.08 aphids/3 leaves (imidacloprid 17.8 SL @3ml/10lits), however *Myzus persicae* population in all the treatments was significantly less than untreated control (20.37 aphids/3 leaves).

Table 4.9: Efficacy of flonicamid and imidacloprid foliar spray against aphid (2018-19)

Treat. No.	Treatments	Dose	Per leaf population of aphid											
			Days after first Spray						Days after second spray					
			PTC	2	4	6	Mean	%ROC	PTC	2	4	6	Mean	%ROC
T1	Control		19.42 (4.46)	20.17 (4.5)	20.70 (4.60)	20.27 (4.55)	20.38	-	18.60 (4.36)	20.37 (4.56)	18.90 (4.40)	17.27 (4.21)	18.84	-
T2	Imidacloprid17.8SL	3ml/10lits	15.28 (3.96)	3.88 (2.05)	2.8 (1.78)	4.85 (2.29)	3.84	81.13	15.86 (4.03)	4.08 (2.10)	3.4 (1.96)	4.85 (2.29)	4.11	78.17
T3	Imidacloprid 17.8SL + repeat at 15 days	3ml/10 lits	17.16 (4.2)	4.25 (2.16)	3.41 (1.97)	3.76 (2.02)	3.81	81.30	17.14 (4.19)	2.05 (1.52)	1.81 (1.42)	2.36 (1.66)	2.07	88.97
T4	Flonicamid 50 WG	3gm / 10 lits	16.73 (4.14)	3.79 (2.04)	3.34 (1.94)	3.78 (2.04)	3.64	82.13	15.84 (4.03)	3.59 (1.99)	3.54 (1.99)	3.78 (2.04)	3.64	80.67
T5	Flonicamid 50 WG + repeat at 15 days	3gm / 10 lits	15.43 (3.98)	3.50 (1.95)	3.34 (1.66)	3.36 (1.94)	3.07	84.92	14.95 (3.92)	1.59 (1.53)	1.34 (1.32)	2.16 (1.60)	1.80	90.41
	SE(m)±		.882	.182	.112	.148			.890	.190	.132	.133		
	CD @ 0.05 %		.264	.546	.338	.445			.266	.572	.132	.198		
	F value		ns	**	**	**			Ns	**	**	**		
PTC:Pre-treatment, H: Hours, ROC:Reduction over control														

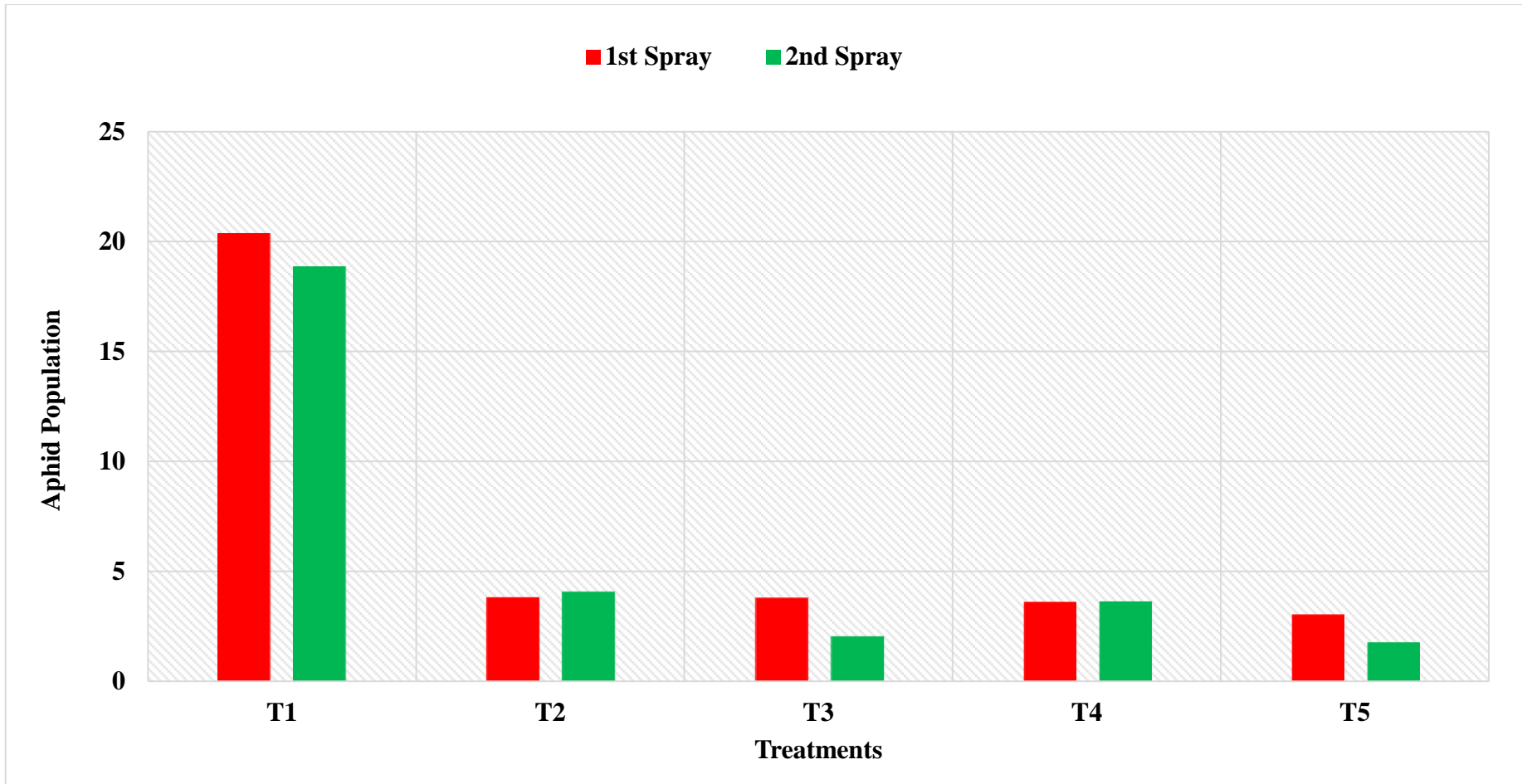


Fig 4.8. Efficacy of flonicamid and imidacloprid foliar spray against aphid (2018-19)

After 4th days of application minimum number of aphid population was minimum 1.34 aphids/3 leaves has been observed in T₄ (flonicamid 50 WG @g/10 lits + repeat at 15 days) followed by 1.81 aphids/3 leaves in T₂ (imidacloprid 17.8 SL @ 3ml/10lits + repeat at 15 days), 3.40 aphids/3 leaves in T₂ (imidacloprid 17.8 SL @ 3ml/10lits), 3.54 aphids/3 leaves in T₄ (flonicamid 50 WG @g/10 lits), however *Myzus persicae* population in all the treatments was significantly less than untreated control (18.90 aphids/3 leaves). Same trend has been observed on 6th days of spray.

On the basis of overall mean population, T₅ was most effective treatment followed by T₃, T₄, and T₂.

It was concluded that treatment T₅ of flonicamid 50 WG@3ml/10lits + repeat at 15 days were the promising treatments as they recorded minimum population after 2nd spray, followed by other treatments and untreated check.

The present findings are in agreement with **Morita *et al.* (2007)** who reported that flonicamid was very effective against aphids, regardless of differences in species, stages, and morphs as this compound inhibited the feeding behavior of aphids within 0.5 h of treatment. **Fonseca *et al.* (2011)** carried out an experiment to evaluate the efficacy of flonicamid against *Aphis gossypii* on cotton crop and reported foliar application was effective in control of the pest. **Scarpellini *et al.* (2011)** conducted a trial to study on aphid *Aphis gossypii*, in the cotton crop with the insecticides flonicamid, thiamethoxam, acetamiprid and imidacloprid and reported that flonicamid presented the highest selectivity for aphid control. A study was conducted by **Bartual *et al.* (2012)** to manage the aphids *Aphis gossypii* and *Aphis punicae*, and the study revealed that new generation insecticide flonicamid was very effective in controlling aphids. **Rouhani *et al.* (2013)** reported that flonicamid at 0.1 mg/ml had the highest mortality against aphids. Flonicamid and dinotefuran were newer chemicals; therefore, research reviews were not available in literature on their effectiveness against aphid on *Bt*cotton. **Kolhe *et al.* (2009)** Imidacloprid and thiamethoxam were statistically at par with flonicamid after 3 days of application. **Ghelani, *et al.* (2014)** the treatments with flonicamid caused significantly maximum mortality of aphid after 3, 7 and 15 days.

4.8.3. Efficacy of imidacloprid and flonicamid against hopper.

The periodical data on population of hopper (*Empoasca devastans*) were recorded on potato one day before and 2nd, 4th and 6th days after each application in cropping season 2018-19 and is presented below:

As indicated in **Table 4.10** before first spray the mean population of hopper varied from 8.20 to 10.24 hopper /3 leaves, no significant difference was observed amongst treatments.

After two days of application minimum number of hopper population, 1.53 hoppers/3 leaves has been observed in T₅ (flonicamid 50 WG @gm/10 lits + repeat at 15 days) followed by 1.85 hoppers/3 leaves in T₂ (imidacloprid 17.8 SL@3ml/10lits), 1.94 hoppers/3 leaves in T₄ (flonicamid 50 WG@gm /10 lits) and 2.15 hoppers/3 leaves in T₃ (imidacloprid 17.8 SL@3ml/10lits + repeat at 15 days), however the population of hopper in all the treatments was significantly less than untreated control (9.43 hoppers/3 leaves).

After 4th day of application minimum number of hoppers population (1.15 hoppers/3 leaves) has been observed in T₂ (imidacloprid 17.8 SL@3ml/10lits) followed by 1.17 hoppers/3 leaves in T₅ (flonicamid 50 WG @g/10 lits + repeat at 15 days), 1.49 hoppers/3 leaves in T₃ (imidacloprid 17.8 SL@3ml/10lits + repeat at 15 days), and 1.53 hoppers/3 leaves T₄ (flonicamid 50 WG @g/10 lits), however the population of hoppers in all the treatments was significantly less than untreated control (10.49 hoppers/3leaves). Same trend has been observed on 6th day of spray.

On the basis of overall mean population, T₅ was most effective treatment followed by T₂, T₄, and T₂.

A perusal of **Table 4.10** indicated that before 2nd spray the mean population of hopper varied from 8.79 to 10.62 /3 leaves no significant difference was observed amongst treatments.

After 2 days of application minimum number of hoppers population was minimum 0.87 hoppers/3leaves has been observed in T₅ (flonicamid 50 WG @g/10 lits + repeat at 15 days) followed by 1.75 hoppers/3leaves in T₃ (imidacloprid 17.8 SL@3ml/10lits + repeat at 15 days), 2.25 hoppers/3leaves in T₂ (imidacloprid 17.8 SL@3ml/10lits) and 2.34 hoppers/3leaves in T₄ (flonicamid 50 WG @g/10 lits), however, the population of hopper in all the treatments was significantly less than untreated control (9.63 hoppers/3 leaves).

Table 4.10: Efficacy of flonicamid and imidacloprid foliar spray green hopper (2018-19)

Treat. No.	Treatments	Dose	Per leaf population of green hopper											
			Days after first Spray						Days after second spray					
			PTC	2	4	6	Mean	%ROC	PTC	2	4	6	Mean	%ROC
T1	Control		10.08 (3.24)	9.43 (3.14)	10.49 (3.30)	10.49 (3.30)	10.13	...	10.62 (3.32)	9.63 (3.17)	10.69 (3.33)	10.49 (3.30)	10.27
T2	Imidacloprid17.8SL	3ml/10lits	8.71 (3.02)	1.85 (1.21)	1.15 (1.26)	1.68 (1.45)	1.56	84.58	8.79 (3.03)	2.25 (1.64)	11.25 (1.35)	2.28 (1.66)	1.96	80.89
T3	Imidacloprid 17.8SL + repeat at 15 days	3ml/10 lits	10.24 (3.27)	2.15 (1.61)	1.49 (1.40)	1.65 (1.45)	1.76	82.57	10.02 (3.23)	1.75 (1.46)	1.09 (1.24)	1.25 (1.31)	1.36	86.71
T4	Flonicamid 50 WG	3gm / 10 lits	8.20 (2.93)	1.94 (1.52)	1.53 (1.41)	1.72 (1.48)	1.73	82.88	8.99 (3.06)	2.34 (1.67)	1.53 (1.41)	1.72 (1.48)	1.86	81.81
T5	Flonicamid 50 WG + repeat at 15 days	3gm / 10 lits	9.27 (3.10)	1.53 (1.38)	1.17 (1.23)	1.21 (1.30)	1.30	87.10	9.84 (3.2)	0.87 (1.13)	0.37 (.92)	0.81 (1.12)	0.68	93.32
	SE(m)±		.123	.139	.121	.919			.118	.138	.952	.983		
	CD @ 0.5 %		.369	.418	.364	.275			.356	.414	.285	.294		
	F value		ns	**	**	**			ns	**	**	**		
PTC: Pre-treatment, H: Hours, ROC: Reduction over control														

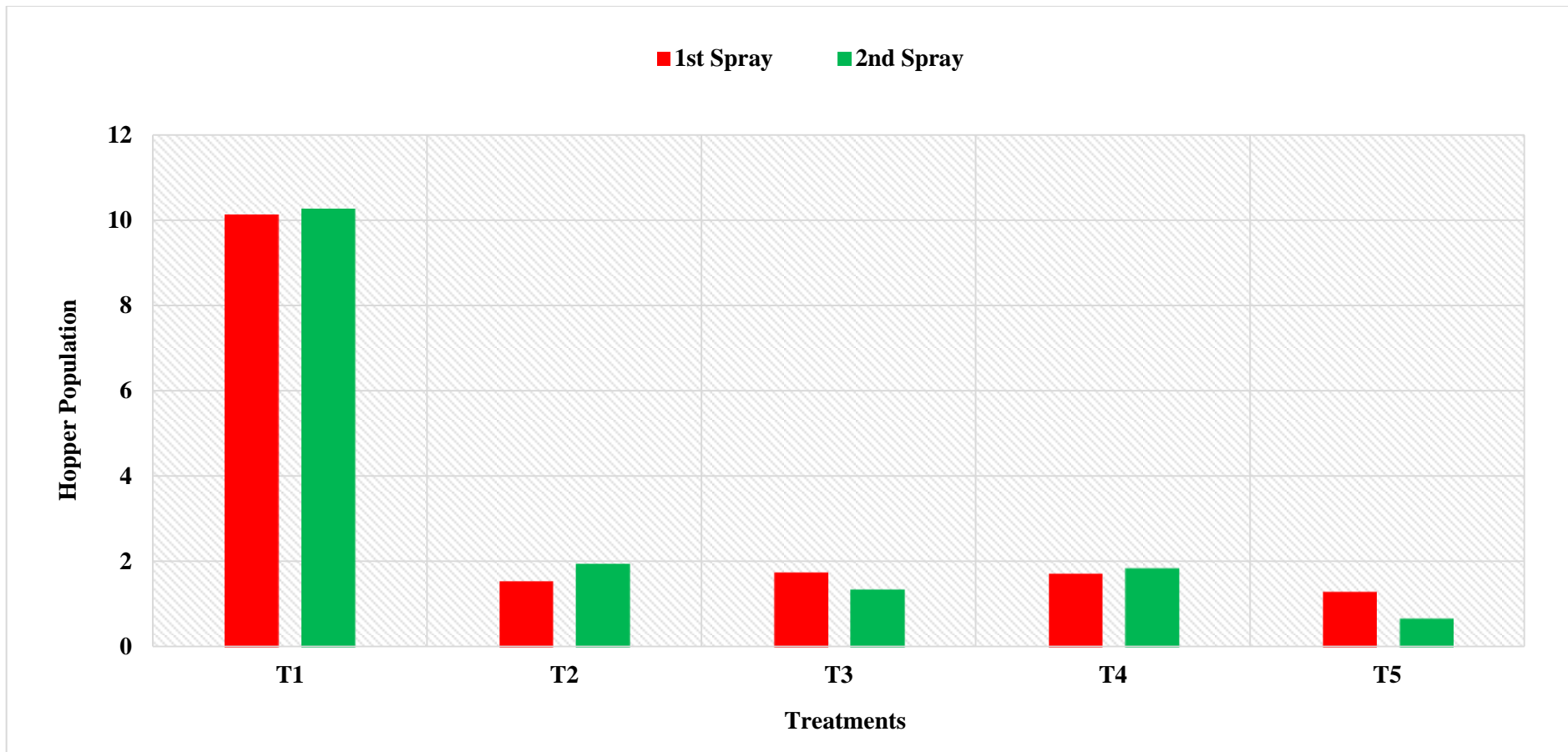


Fig 4.9.Efficacy of flonicamid and imidacloprid foliar spray green hopper (2018-19)

After 4th day of application minimum number of hopper population was minimum 0.37 hopper/3 leaves has been observed in T₅ (flonicamid 50 WG @g/10 lits + repeat at 15 days) followed by 1.09 hopper/3leaves in T₂ imidacloprid 17.8 SL@3ml/10lits + repeat at 15 days), 1.25 hoppers/3 leaves in imidacloprid 17.8 SL@3ml/10lits) and 1.53 hoppers/3 leaves in T₄ (flonicamid 50 WG @g/10 lits), however the population of hopper in all the treatments was significantly less than untreated control (9.98 hoppers/3leaves). Same trend has been observed on after 6th days of spray.

On the basis of overall mean population, T₅ was most effective treatment followed by T₃, T₄, and T₂.

It was concluded that treatment T₅ of flonicamid 50 WG@3ml/10lits + repeat at 15 days were the promising treatments as they recorded minimum population after 2nd spray, followed by other treatments and untreated check.

Misra (2009) screened four insecticides including flonicamid 50 WG, imidacloprid 17.8 SL, thiamethoxam 25% WG and clothianidin 50 WDG against the brown plant hopper, *Nilaparvata lugens* (Stal.) and showed that low BPH population (1.40-1.30/hill) was observed with flonicamid 50 WG @ 150 g a.i./ha with a reduction of 90.30% over untreated control. **Ravikumar (2014)** reported among the different insecticides tested flonicamid 10 WG were able to reduce the population of jassid (3.17 /3leaves/plant).

4.8.4. Efficacy of imidacloprid and flonicamid against thrips.

The periodical data on population of thrips (*Thrips palmi*) were recorded on potato one day before and 2rd, 4th and 6th days after each application in cropping season 2018-19 and is presented below:

Table 4.11 revealed that before first spray the mean population of thrips varied from 13.18 to 15.36 thrips /3 leaves, no significant difference was observed amongst treatments.

After two days of application minimum number of population, 2.70 thrips/3 leaves has been observed in T₅ (flonicamid 50 WG @3ml/10lits + repeat at 15 days) followed by 3.05 thrips/3 leaves in T₃ (imidacloprid 17.8 SL@3ml/10 lits + repeat

15days), 4.05 thrips/3 leaves in flonicamid 50 WG @3ml/10lits), 4.28 thrips/3 leaves in T₂ (imidacloprid 17.8 SL@3ml/10 lits), however the *Thrips palmi* population in all the treatments was significantly less than untreated control (13.96 thrips/3 leaves).

After 4th days of application minimum number of population, 1.94 thrips/3 leaves has been observed in T₅ (flonicamid 50 WG @3ml/10lits + repeat at 15 days followed by 2.61 thrips/3 leaves in T₃ (imidacloprid 17.8 SL@3ml/10 lits + repeat 15days), 3.20 thrips/3 leaves in T₂ (imidacloprid 17.8 SL @3ml/10 lits) and 3.74 thrips/3 leaves in T₄ (flonicamid 50 WG @3ml/10lits), however the *Thrips palmi* population in all the treatments was significantly less than untreated control (13.96 thrips/3 leaves).

Same trend has been observed after 6th days spray.

On the basis of overall mean population, T₅ was most effective treatment followed by T₃, T₂, and T₄.

Table 4.11 revealed that before 2nd spray the mean population of thrips varied from 12.76 to 14.16 thrips /3 leaves, no significant difference was observed amongst treatments.

After 2 days of application minimum number of thrips population was minimum 1.90 thrips /3 leaves) has been observed in T₅ (flonicamid 50 WG@3ml/10lits + repeat at 15 days) followed by 1.85 thrips/3 leaves in T₂ (imidacloprid 17.8 SL@3ml/10 lits + repeat 15days), 3.99 thrips/3 leaves in T₄ (flonicamid 50 WG @3ml/10lits) and 4.28 thrips/3 leaves in T₂ (imidacloprid 17.8 SL@3ml/10 lits), however the *Thrips palmi* population in all the treatments was significantly less than untreated control (13.16 Thrips/3 leaves).

After 4th days of application minimum number of population was minimum 1.34 thrips/3 leaves) has been observed in T₅ (flonicamid 50 WG @3ml/10lits + repeat at 15 days) followed by 2.21 thrips/3 leaves in T₃ (imidacloprid 17.8 SL@3ml/10 lits + repeat 15days), 2.40 thrips/3 leaves in flonicamid 50 WG @3ml/10lits) and 3.14 thrips/3 leaves in T₂ (imidacloprid 17.8 SL@3ml/10 lits), However the *Thrips palmi* population in all the treatments was significantly less than untreated control (13.96 thrips/3leaves). Same trend has been observed on after 6th days spray.

Table 4.11: Efficacy of flonicamid and imidacloprid foliar spray against thrips(2018-19)

Treat. No.	Treatments	Dose	Per leaf population of thrips											
			Days after first Spray						Days after second spray					
			PTC	2	4	6	Mean	%ROC	PTC	2	4	6	Mean	%ROC
T1	Control		15.36 (3.97)	13.96 (3.80)	13.96 (3.80)	13.96 (3.80)	13.96	-	12.76 (3.62)	13.16 (3.69)	13.96 (3.79)	12.56 (3.61)	13.23	-
T2	Imidacloprid 17.8SL	3ml/10lit	14.56 (3.86)	4.28 (2.16)	3.2 (1.92)	3.65 (2.02)	3.71	73.40	13.96 (3.78)	4.28 (2.16)	2.4 (1.67)	3.85 (2.07)	3.51	73.45
T3	Imidacloprid 17.8SL + repeat at 15 days	3ml/10 lit	14.18 (3.82)	3.05 (1.87)	2.61 (1.75)	3.56 (1.96)	3.07	77.96	13.98 (3.79)	1.85 (1.49)	2.21 (1.57)	2.76 (1.78)	2.27	82.79
T4	Flonicamid 50 WG	3gm / 10 lits	13.96 (3.80)	4.05 (2.11)	3.74 (2.04)	3.78 (2.04)	3.86	72.34	14.16 (3.82)	3.99 (2.08)	3.14 (1.89)	3.78 (2.04)	3.64	72.48
T5	Flonicamid 50 WG + repeat at 15 days	3gm / 10 lits	13.18 (3.69)	2.70 (1.76)	1.94 (1.55)	3.96 (1.07)	2.87	79.42	13.92 (3.78)	1.90 (1.50)	1.34 (1.32)	1.49 (1.60)	1.67	87.36
	SE(m)±		.129	.135	.799	.178			.146	.154	.162	.897		
	CD @ 0.5 %		.388	.406	.239	.534			.440	.461	.488	.269		
	CV (%)		7.56	12.93	10.54	16.73			8.72	15.73	17.75	9.11		
	F value		ns	**	**	**			ns	**	**	**		
PTC:Pre-treatment, H: Hours, ROC:Reduction over control														

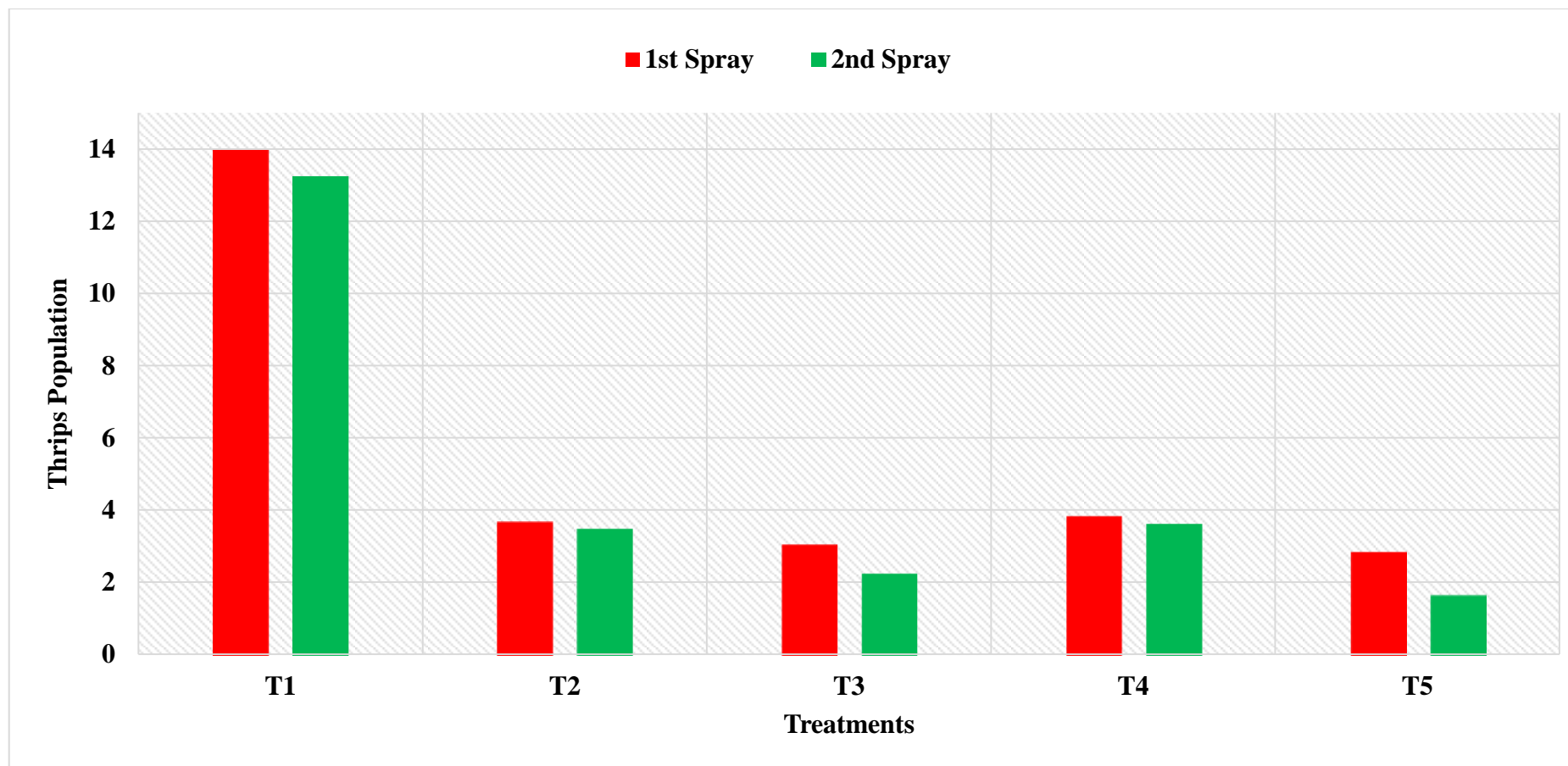


Fig 4.10. Efficacy of flonicamid and imidacloprid foliar spray against thrips(2018-19)

On the basis of overall mean population, T₅ was most effective treatment followed by T₃, T₂, and T₄.

It was concluded that treatment T₅ of flonicamid 50 WG@3ml/10lits + repeat at 15 days were the promising treatments as they recorded minimum population after 2nd spray, followed by other treatments and untreated check.

Sathyan et al. (2016), reported flonicamid 50 WG and imidacloprid 17.8 SL were able to reduce the population of thrips by more than 45 percent and flonicamid 50 WG, imidacloprid 17.8 SL was found more effective against sucking insect pest's viz., leafhopper, aphid, thrips, and whitefly infesting cotton. **Ghelani et al. (2014)** significant difference in mortality of thrips was found due to insecticidal treatments after 3, 7 and 15 days of their applications. After 3, 7 and 15 days of application, flonicamid caused significantly maximum mortality of thrips. **Bambhaniya et al. (2018)** reported per cent reduction in pest population over control of thrips recorded at the second day after spraying in Imidacloprid 0.005 per cent with 37.63 per (2.27 thrips/3 leaves), flonicamid 0.015 per cent with 35.22 per cent (2.32 thrips/3 leaves),

4.9. Effect of different treatments on the population of natural enemies during crop season 2018-19

4.9.1 Impact on ladybird beetle (*Coccinella septumpunctata*)

The population of grubs and adults of ladybird beetle in each treatment was recorded after 2nd, 4th and 6th days of insecticidal application. The data are summarized below.

The number of ladybird beetles observed before spray varied from 1.82 to 3.53 ladybird beetles/plant. At 2nd day after spray, coccinellids population varied from (0.99 coccinellids /plant) with flonicamid 50 WG @3ml/10lits + repeat at 15 days followed by imidacloprid 17.8 SL@3ml/10 lits + repeat 15days (1.32 ladybird beetles/plant), imidacloprid 17.8 SL @3ml/10 lits (1.39 ladybird beetles/plant), flonicamid 50 WG @3ml/10lits (1.40 ladybird beetles/plant),

At 4th day after spray, coccinellids population varied from (1.18 coccinellids /plant) with imidacloprid 17.8 SL@3ml/10 lits + repeat 15days followed by imidacloprid 17.8 SL@3ml/10 lits (1.55 ladybird beetles/plant), flonicamid 50 WG @3ml/10lits +

repeat at 15 days (1.56 ladybird beetles/plant), flonicamid 50 WG @3ml/10lits (1.64 ladybird beetles/plant),

At 6th day after spray, coccinellid population varied from (1.12 coccinellids/plant) with imidacloprid 17.8SL @3ml/10 lits + repeat 15days followed by imidacloprid 17.8 SL@3ml/10 lits (1.23 ladybird beetles/plant), flonicamid 50 WG @3ml/10lits + repeat at 15 days (2.12 Ladybird beetles/plant) flonicamid 50 WG @3ml/10lits (2.54 ladybird beetles/plant),

On the basis of overall mean population, T₄ was most effective treatment followed by T₂, T₅, and T₃.

A perusal of data collected one day before 2nd spray revealed that the number of ladybird beetles observed was 1.87 coccinellids/plant to 3.27 coccinellid /plant.

At the 2nd day after spray, coccinellid population varied from (1.29 coccinellids/plant) with imidacloprid 17.8 SL@3ml/10 lits followed by, imidacloprid 17.8 SL@3ml/10 lits + repeat 15days (1.37 ladybird beetle/plant). flonicamid 50 WG @3ml/10lits + repeat at 15 days (1.42 ladybird beetle/plant), flonicamid 50 WG@3ml/10lits (1.45 ladybird beetle/plant). At 4th day after spray, coccinellids population varied from imidacloprid 17.8SL@3ml/10 lits + repeat 15days (0.46 ladybird beetles/plant), followed by flonicamid 50 WG@3ml/10lits + repeat at 15 days (1.14 ladybird beetles/plant), imidacloprid 17.8 SL@3ml/10 lits (1.03 ladybird beetles/plant, flonicamid 50 WG @3ml/10lits (1.22 ladybird beetles/plant).

At 6th day after spray, coccinellids population varied from imidacloprid 17.8 SL@3ml/10 lits + repeat 15days (0.60 ladybird beetles/plant), followed by imidacloprid 17.8 SL@3ml/10 lits (0.95 ladybird beetles/plant), flonicamid 50 WG@3ml/10lits (1.16 ladybird beetles/plant), flonicamid 50 WG@3ml/10 lits + repeat at 15 days (1.15 ladybird beetles/plant).

On the basis of overall mean population, T₃ was most effective treatment followed by T₂, T₂, and T₅.

A comparison of data during the cropping season *Winter* 2018-19, after the application of insecticides in different treatments revealed that the application of flonicamid 50 WG@ 3ml/10 lits were the safest insecticides as they recorded a maximum population of natural enemies after two spray, followed by other treatment.

Table 4.12: Effect of flonicamid and imidacloprid foliar spray against coccinellids (2018-19)

Treat. No.	Treatments	Dose	Number of coccinellids per plant									
			Days after first Spray					Days after second spray				
			PTC	2	4	6	Mean	PTC	2	4	6	Mean
T1	Control	-	3.53 (2.00)	3.53 (2.00)	4.16 (2.15)	4.26 (2.18)	3.98	3.27 (1.94)	3.00 (1.86)	2.49 (1.70)	2.77 (1.80)	2.75
T2	Imidacloprid17.8SL	3ml/10lit	1.91 (1.54)	1.39 (1.37)	1.55 (1.42)	1.23 (1.31)	1.39	2.03 (1.56)	1.29 (1.33)	1.03 (1.21)	0.95 (1.18)	1.09
T3	Imidacloprid 17.8SL + repeat at 15 days	3ml/10 lit	1.82 (1.51)	1.32 (1.34)	1.18 (1.28)	1.12 (1.26)	1.21	2.20 (1.62)	1.37 (1.36)	0.46 (0.97)	0.60 (1.03)	0.81
T4	Flonicamid 50 WG	3gm / 10 lits	2.48 (1.72)	1.40 (1.37)	1.64 (1.46)	2.54 (1.74)	1.86	1.87 (1.51)	1.45 (1.39)	1.22 (1.28)	1.16 (1.28)	1.28
T5	Flonicamid 50 WG + repeat at 15 days	3gm / 10 lits	2.37 (1.69)	0.99 (1.85)	1.56 (1.83)	2.12 (1.61)	1.56	2.43 (1.70)	1.42 (1.38)	1.14 (1.27)	1.15 (1.17)	1.24
	SE(m)±		.393	.389	.424	.386		.179	.326	.113	.673	
	CD @ 0.5 %		.118	.116	.485	.115		.350	.977	.340	.201	
	F value		ns	**	**	**		ns	**	**	**	
PTC:Pre-treatment H: Hours												

Table 4.13: Effect of flonicamid and imidacloprid foliar spray against spiders (2018-19)

Treat. No.	Treatments	Dose	Number of spiders per plant									
			Days after first Spray					Days after second spray				
			PTC	2	4	6	Mean		2	4	6	Mean
T1	Control	-	1.66 (1.46)	1.76 (1.50)	2.23 (1.64)	3.32 (1.95)	2.44	3.13 (1.90)	3.17 (1.91)	3.57 (2.01)	3.37 (1.96)	3.37
T2	Imidacloprid 17.8SL	3ml/10lit	1.36 (1.36)	0.60 (1.02)	0.77 (1.06)	1.06 (1.24)	0.81	1.79 (1.50)	1.36 (1.36)	1.01 (1.20)	1.00 (1.95)	1.13
T3	Imidacloprid 17.8SL + repeat at 15 days	3ml/10 lit	1.38 (1.37)	0.55 (1.01)	0.65 (1.06)	0.92 (1.19)	0.71	1.74 (1.49)	1.31 (1.34)	0.46 (0.97)	0.79 (1.11)	0.85
T4	Flonicamid 50 WG	3gm / 10 lits	1.33 (1.32)	1.38 (1.37)	1.33 (1.35)	1.57 (1.43)	1.43	2.56 (1.74)	2.35 (1.68)	1.17 (1.27)	0.79 (1.33)	1.62
T5	Flonicamid 50 WG + repeat at 15 days	3gm / 10 lits	1.38 (1.34)	1.06 (1.24)	1.15 (1.28)	1.47 (1.40)	1.23	2.24 (1.74)	1.53 (1.68)	1.14 (1.27)	1.34 (1.24)	1.26
	SE(m)±		.386	.719	.720	.460		.476	.215	.216	.110	
	CD @ 0.5 %		.115	.215	.216	.138		.142	.726	.723	.330	
	F value		ns	**	**	**		ns	**	**	**	
PTC: Pre-treatment H: Hours												

Pawar and Bharpoda (2013) also found that flonicamid @ 0.015% was safer to the larval population of coccinellids in safflower. Similarly, **Jansen et al. (2011)** reported flonicamid 50 WG @ 80 g a.i. ha⁻¹ as non-toxic to hoverflies, ladybirds, parasitic Hymenoptera, carabid, and rove beetles **Kar (2017)**. This result revealed that imidacloprid had a more adverse effect on coccinellids.

4.9.2. Impact on spiders (*Oxyopes satticus*)

The population of spiders in each treatment was recorded after 2nd, 4th and 6th days of insecticidal application. The data are summarized below. The average number of spider/plants observed just before 1st spray varied from 1.33 spiders/plant to 1.38 spiders/plant. At 2nd day after spray, Spiders population varied from (0.55 spiders/plant) with imidacloprid 17.8 SL@3ml/10 lits + repeat 15 days, followed by imidacloprid 17.8 SL@3ml/10 lits (0.60 spiders/plant), flonicamid 50 WG @3ml/10lits + repeat at 15 days (1.06 spiders/plant), flonicamid 50 WG @3ml/10lits (1.38 spiders/plant).

At 4th day after spray spiders population varied from (0.65 spiders /plant) with imidacloprid 17.8 SL@3ml/10 lits + repeat 15days followed by imidacloprid 17.8 SL@3ml/10 lits (0.77 spiders/plant), flonicamid 50 WG@3ml/10lits + repeat at 15 days (1.15 spiders/plant), flonicamid 50 WG@3ml/10lits (1.33 spiders/plant).

At 4th day after spray spiders population varied from (0.92 spiders /plant) with imidacloprid 17.8 SL@3ml/10 lits + repeat 15days followed by imidacloprid 17.8 SL@3ml/10 lits (1.06 spider/plant), flonicamid 50 WG@3ml/10lits + repeat at 15 days (1.47 spiders/plant), flonicamid 50 WG@3ml/10lits (1.43 spiders/plant).

On the basis of overall mean population, T₅ was most effective treatment followed by T₄, T₂, and T₃.

A perusal of data collected one day before 2nd spray, revealed that the number of spiders observed were 1.74 to 3.13. At 2rd day after spray, spiders population varied from (1.31 spiders/plant) with imidacloprid 17.8 SL@3ml/10 lits + repeat 15days followed by imidacloprid 17.8 SL @3ml/10 lits (1.36 spiders/plant), flonicamid 50 WG @ 3ml/10lits + repeat at 15 days (1.53 spiders/plant), flonicamid 50 WG @3ml/10lits (2.35 spiders/plant)

At 4th day after spray, spiders population varied from (0.46 spiders/plant) with imidacloprid 17.8 SL@3ml/10 lits + repeat 15days followed by imidacloprid 17.8

SL@3ml/10 lits (1.01 spiders/plant), flonicamid 50 WG @3ml/10lits + repeat at 15 days (1.14 spiders/plant), flonicamid 50 WG @3ml/10lits (1.17 spider/plant),

At 6th day after spray, spiders population varied from (0.79 spiders/plant) with imidacloprid 17.8 SL@3ml/10 lits + repeat 15 days followed by flonicamid 50 WG @3ml/10lits (0.79 spiders/plant), imidacloprid 17.8 SL@3ml/10 lits (1.00 spiders/plant), flonicamid 50 WG @3ml/10lits + repeat at 15 days (1.34 spiders/plant).

On the basis of overall mean population, T₃ was most effective treatment followed by T₂, T₅, and T₄.

A comparison of data during the cropping season *Winter* 2018, after the application of insecticides in different treatments revealed that the application of flonicamid 50 WG @3ml/10lits were the safest insecticides as they recorded maximum population of natural enemies after two sprays, followed by other treatment.

A perusal of the data obtained above revealed that the population of natural enemies was noticeably lower after application of insecticides up to 4 days. Thereafter, the population of natural enemies gradually increased in plots treated with flonicamid during the season *Rabi*, 2018.

Kodandaram *at al.* (2017) reported flonicamid 50 WG did not cause any phytotoxic symptoms. It was also safe to the natural enemies (spiders and rove beetles) **Kar (2017)** Bioefficacy evaluation of imidacloprid 17.8% SL and thiamethoxam against whitefly on tomato and their effect on natural enemies. The insecticides showed no effect on the population of spider even at a higher dose of spray. On the other hand maximum reduction of coccinellid, population was recorded when imidacloprid 17.8% SL was applied @ 175ml/ha followed by 150 ml/ha at 3 and 7 days after spray.

4.10. Effect of flonicamid and imidacloprid on the yield of potato as a foliar application

Data on marketable yield in kg /plot and ton/ha during the crop season *winter*, 2019 indicated that the yield of potato tuber under different insecticidal treatment varied significantly from 18.6 to 16.54 T/ha. Maximum tuber yield (41.67 T/ha) was recorded from plots treated with flonicamid 50 WG + repeat at 15 days which is significantly differed from all other treatments. This was followed by imidacloprid 17.8SL + repeat at 15 days (38.33 T/ha), flonicamid 50 WG (35.67 T/ha), imidacloprid 17.8SL (34.33 T/ha), control (31.00 T/ha).

Table 4.14: Effect of flonicamid and imidacloprid on yield of potato after foliar application (2018-19)

Treatment		Dose	Yield of marketable fruits		
			Kg/plot	T/ha	% increase over control
T1	Control		18.6	31.00	-
T2	Imidacloprid 17.8 SL	3 ml/10 lits	20.6	34.33	10.74
T3	Imidacloprid 17.8 SL + repeat at 15 days	3 ml/10 lits	23	38.33	23.60
T4	Flonicamid 50 WG	3 gm / 10 lits	21.4	35.67	15.06
T5	Flonicamid 50 WG + repeat at 15 days	3 gm / 10 lits	25	41.67	34.41
	SEm±	-	0.981	-	-
	CD at 0.5%	-	2.966	-	-

Kg: Kilogram ; T: Tone ; ha: Hectare

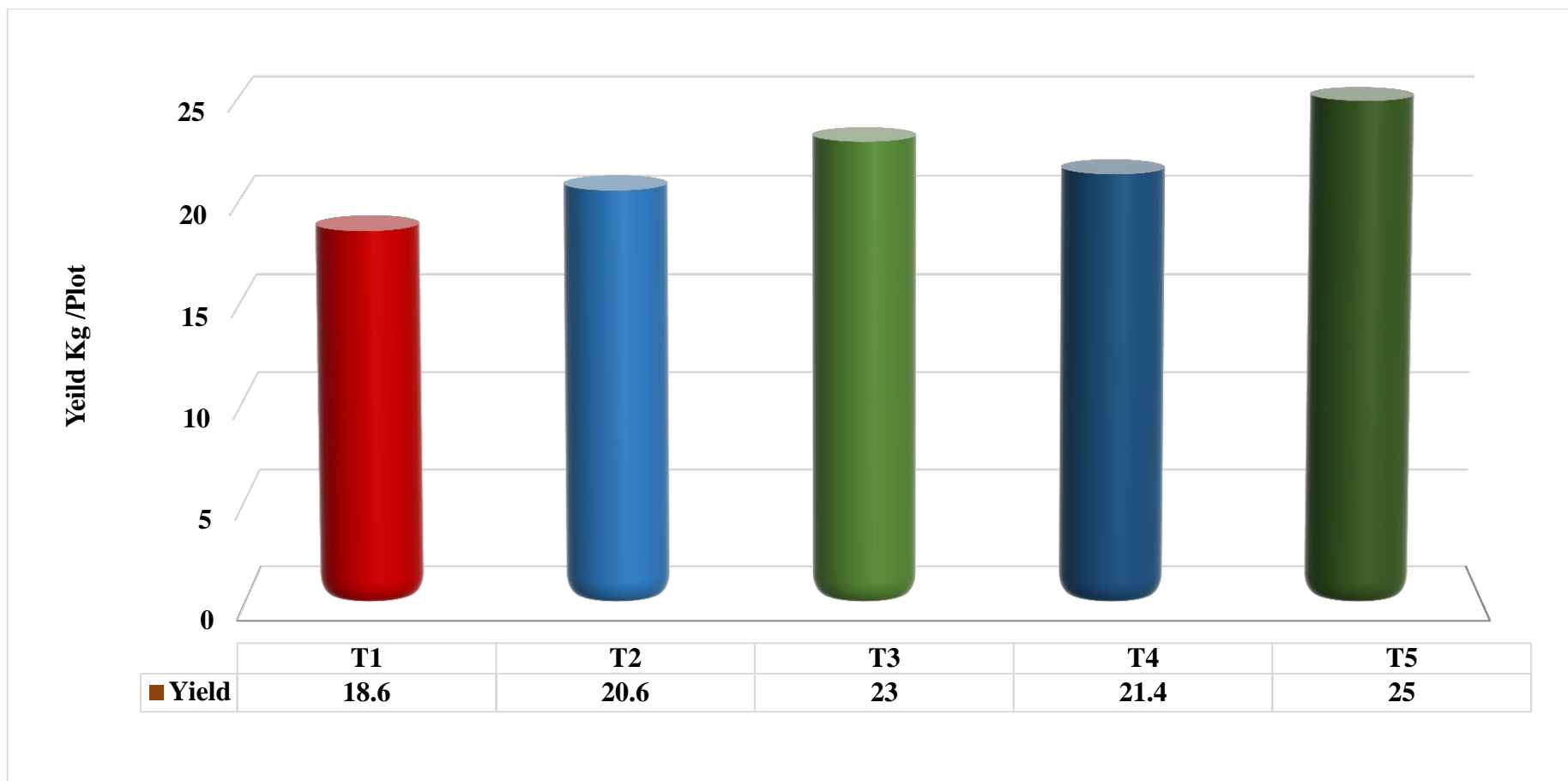


Fig 4.11. Effect of flonicamid and imidacloprid on yield of potato after foliar application (2018-19)

Ghelani et al. (2014) Data on yield and economics revealed that significantly higher yield of seed cotton was recorded in the treatments with flonicamid 0.02 per cent and acetamiprid 0.004 per cent followed by imidacloprid 0.0089 percent, dinotefuran 0.008 per cent and thiamethoxam 0.01 per cent.

4.11 Bioefficacy of some novel insecticides as foliar spray and seed treatment against insect pests of potato.

The efficacy of various treatments which include imidacloprid, thiamethoxam, diafenthiuron and castor oil in combination at different doses was evaluated against sucking insect pests of potato crop.

4.11.1. Efficacy of various treatments on the population of whitefly, *Bemisia tabaci* (Gennadius) during crop season 2018-19

The periodical data on population of whitefly (*B. tabaci*) were recorded on potato one day before and 24, 48 and 72 hours after each application during the cropping season 2018-19 is presented below:

After studying **Table 4.15** it was find out that before first spray the mean population of whitefly varied from 12.35 to 15.92 whitefly/3 leaves, no significant difference was observed amongst treatment.

After 24 hours of application minimum number of whitefly population, 1.74 whitefly/3 leaves has been observed in T₂ and T₃ followed by 2.08 whitefly/3 leaves in T₄, 2.6 whitefly/3 leaves in T₅, 2.54 whitefly/3 leaves in T₆, 3.19 whitefly/3 leaves in T₇, however whitefly, population in all the treatments was significantly less than untreated control (12.75 whitefly/3 leaves).

After 48 hours of application minimum number of whitefly population, 1.17 whitefly/3 leaves has been observed in T₂ followed by 1.27 whitefly/3 leaves in T₇, 1.43 whitefly/3 leaves in T₄, 2.09 whitefly/3 leaves in T₆, 2.21 whitefly/3 leaves in T₃, 2.83 whitefly/3 leaves in T₅, however *Bemisia tabaci* population in all the treatments was significantly less than untreated control (13.15 whitefly/3 leaves). Same trend has been observed on 72 hours of spray.

On the basis of overall mean population, T₂ was most effective treatment followed by T₃, T₄, T₆, T₇ and T₅.

Table 4.15: Efficacy of different insecticidal foliar spray and seed treatment against whitefly (2018-19)

Treatment	Dose	Pre-spray count	Hours after first spray			Mean	% ROC	Pre-spray count	Hours after second spray			Mean	% ROC
			24H	48H	72H				24H	48H	72H		
T1 Control	-	12.35 (3.56)	12.75 (3.61)	13.15 (3.67)	14.77 (3.90)	13.56	-	10.45 (3.29)	10.96 (3.37)	11.96 (3.52)	12.93 (3.65)	11.95	-
T2 Imidacloprid 200 SL(ST) + Imidacloprid @60 g a.i./ha (FS) + Thiamethoxam 25 WG (SS)	0.036g a.i/Plot 0.06g a.i/Plot	15.3 (3.96)	1.74 (1.48)	1.17 (1.28)	1.18 (1.28)	1.36	89.93	15.7 (4.00)	1.01 (1.21)	0.74 (1.07)	1.11 (1.27)	0.95	91.98
T3 Diafenthiuron 50 WP(FS)	0.210g a.i/Plot	15.92 (4.05)	1.74 (1.48)	2.21 (1.30)	1.26 (1.28)	1.40	89.62	15.72 (4.02)	2.01 (1.58)	2.11 (1.60)	2.04 (1.58)	2.05	82.77
T4 Diafenthiuron 50 WP (FS) + Diafenthiuron 50 WP (SS)	0.210g a.i/Plot	15.39 (3.96)	2.08 (1.59)	1.43 (1.36)	2.01 (1.58)	1.84	86.40	15.99 (4.04)	1.50 (1.40)	1.2 (1.23)	1.63 (1.44)	1.44	87.88
T5 Castor oil @ 0.05(FS)	0.15 ml/Plot	14.30 (3.82)	3.19 (1.91)	2.83 (1.81)	2.29 (1.65)	2.77	79.53	14.30 (3.82)	2.55 (1.74)	2.13 (1.61)	2.05 (1.59)	2.24	81.19
T6 Diafenthiuron 50 WP(FS)+ Castor oil @ 0.05	0.210g a.i/Plot 0.15 ml/Plot	13.97 (3.79)	2.54 (1.72)	2.09 (1.59)	1.14 (1.21)	1.92	85.77	13.97 (3.79)	1.86 (1.52)	1.65 (1.46)	2.11 (1.58)	1.87	84.27
T7 Diafenthiuron 50 WP (FS)+ Castor oil, Diafenthiuron (SS)	0.210g a.i/Plot 0.15 ml/Plot	13.37 (3.71)	2.26 (1.66)	1.27 (1.33)	2.16 (1.56)	1.90	85.97	13.14 (3.68)	1.61 (1.44)	1.53 (1.42)	1.78 (1.48)	1.63	86.35
CD at 0.05%		.419	.348	.328	.420			.495	.242	.360	.264		
SEM±		.143	.119	.112	.144			.169	.829	.123	.904		
F value		ns	**	**	**			ns	**	**	**		

ST: Seed Treatment, FS: Foliar spray after 85 % emergence, SS: Second spray, H: Hours, ROC: Reduction over control

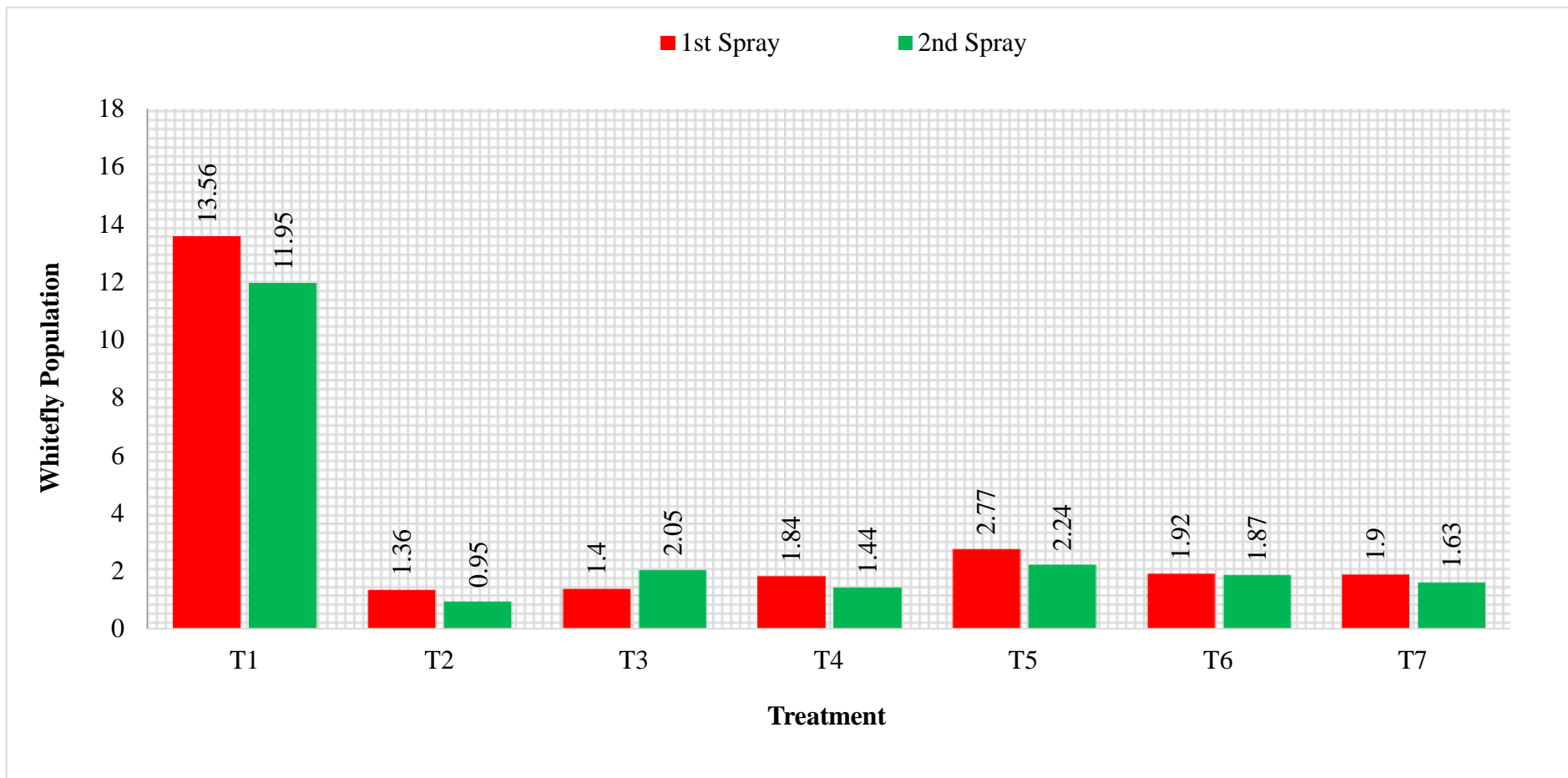


Fig 4.12. Efficacy of different insecticidal foliar spray and seed treatment against whitefly (2018-19)

A perusal of **table 4.15** indicated that before 2nd spray the mean population of whitefly varied from 10.45 to 15.99 /3 leaves no significant difference was observed amongst treatments.

After 24 hours of application minimum number of whitefly population, 1.01 Whitefly/3 leaves) has been observed in T₂ followed by 1.50 whitefly/3 leaves in T₄, 1.61 whitefly/3 leaves in T₇, 1.86 whitefly/3 leaves in T₆, 2.01 whitefly/3 leaves in T₃ and 2.55 whitefly/3 leaves T₅, however the *Bemisia tabaci* population in all the treatments was significantly less than untreated control (10.96 whitefly/3 leaves).

After 48 hours of application minimum number of whitefly population, 0.74 whitefly/3 leaves has been observed in T₂ followed by 1.20 whitefly/3 leaves in T₄, 1.53 whitefly/3 leaves in T₇, 1.65 whitefly/3 leaves T₆, 2.11 whitefly/3 leaves in T₃, and T₅ in 2.13 whitefly/3 leaves, however the whitefly population in all the treatments was significantly less than untreated control (11.96 whitefly/3leaves).

Same trend has been observed on 72 hours of spray.

On the basis of overall mean population, T₂ was most effective treatment followed by T₄, T₇, T₅, T₃ and T₅.

It was concluded that treatment T2 which includes the application of seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar spray of imidacloprid @60 g a.i./ha at 85% emergence + second spray with thiamethoxam 25 WG @ 100g a.i./ha was most promising treatment as they recorded minimum population after two sprays, followed by other treatments and untreated check.

Sharaf et al. (2003) reported that confidor and Best also induced the highest initial activity on immature stages of whitefly. **Khattak et al. (2004)** found that thiamethoxam (Actara) as well as imidacloprid (confidor) reduced the mean percent population of whiteflies even 240 h after spraying. **Asi et al. (2008)** found that imidacloprid was effective against whiteflies and jassids up to 168 h after spraying. **Abbas et al. (2012)** population reduction of the three insect pests to 7 days post-treatment on all tested cotton cultivars. However, Crown, Actar, and Assault proved to be highly effective against jassid and whitefly, the performance of tested insecticides was affected by the cultivars against whitefly. Crown 24 h post application caused maximum population reduction (91%). **Jakhar et al. (2016)** reported that seed

treatment of moth bean with imidacloprid 17.8 SL @ 0.005 percent or thiamethoxam 35 FS @ 5 g/kg seed was found highly effective for the control of whitefly. **Bajya et al. (2016)**. study the comparative bioefficacy of diafenthiuron 47.8 SC, @ 286.8 g a.i./ha was highly effective in suppressing the sucking pests viz., *Amrasca biguttula biguttula* (Ishida), *Aphis gossypii* (Glover), *Bemisia tabaci* (Gennadius) and *Scirtothrips dorsalis* Hood, and it had no adverse effects on the natural enemies.

4.11.2. Efficacy of various treatments on the population of aphid (*Myzus persicae*) during crop season 2018-19

The periodical data on population of aphid (*Myzus persicae*) were recorded on potato one day before and 24, 48 and 72 Hours days after each application during the cropping season 2018-19 is presented below:

Perusal at **table 4.16** indicated that before first spray the mean population of aphid varied from 14.58 to 19.42 aphid/3 leaves, no significant difference was observed amongst treatment.

After 24 hours of application minimum number of aphid population, 1.68 aphid/3 leaves has been observed in T₇ followed by 1.68 aphid/3 leaves in T₅, 1.75 aphid/3 leaves in T₆, 1.78 aphid/3 leaves in T₄, 2.01 aphid/3 leaves in T₂ and 2.57 aphid/3 leaves T₃, however the aphid population in all the treatments was significantly less than untreated control (12.78 aphid/3 leaves).

After 48 hours of application minimum number of whitefly population, 1.05 aphid/3 leaves) has been observed in T₂ followed by 1.18 aphid/3 leaves in T₄, 1.19 aphid/3 leaves in T₅, 1.26 aphid/3 leaves in T₆, 1.60 aphid/3 leaves in T₇ and 1.90 aphid/3 leaves T₃, however, the *Myzus persicae* population in all the treatments was significantly less than untreated control (12.18 aphid/3 leaves). Same trend has been observed on 72 hours of spray.

On the basis of overall mean population, T₂ was most effective treatment followed by T₇, T₂, T₄, T₅ and T₆.

Perusal at **table 4.16** indicated that before 2nd spray the mean population of aphid varied from 13.36 to 18.88 aphid/3 leaves, no significant difference was observed amongst treatment.

Table 4.16: Efficacy of different insecticides foliar spray and seed treatment against aphid (2018-19)

Treatment		Dose	Pre-spray count	Hours after first spray			Mean	% ROC	Pre-spray count	Hours after second spray			Mean	% ROC
				24H	48H	72H				24H	48H	72H		
T1	Control	-	14.58 (3.87)	12.78 (3.63)	12.18 (3.54)	14.18 (3.79)	13.04	-	13.36 (3.71)	12.87 (3.65)	12.08 (3.54)	14.18 (3.79)	13.04	-
T2	Imidacloprid 200 SL(ST) + Imidacloprid @60 g a.i./ha (FS) +Thiamethoxam 25 WG (SS)	0.036g a.i/Plot 0.6g a.i/Plot	15.53 (3.99)	2.01 (1.55)	1.05 (1.21)	1.09 (1.18)	1.38	89.38	15.72 (4.01)	1.29 (1.33)	0.82 (1.12)	0.69 (1.06)	0.934	92.83
T3	Diafenthiuron 50 WP(FS)	0.210g a.i/Plot	19.42 (4.46)	2.57 (1.70)	1.9 (1.52)	1.36 (1.30)	1.95	84.99	18.88 (4.40)	2.57 (1.70)	2.82 (1.80)	2.36 (1.68)	2.58	80.15
T4	Diafenthiuron 50 WP (FS) + Diafenthiuron 50 WP (SS)	0.210g a.i/Plot	15.28 (3.96)	1.78 (1.48)	1.18 (1.29)	1.22 (1.20)	1.39	89.33	15.24 (3.96)	1.79 (1.51)	1.34 (1.35)	1.22 (1.20)	1.45	88.85
T5	Castor oil @ 0.05(FS)	0.15 ml/Plot	17.16 (4.20)	1.68 (1.45)	1.19 (1.30)	1.62 (1.31)	1.5	88.49	16.95 (4.17)	1.99 (1.57)	1.77 (1.49)	1.42 (1.67)	2.06	84.16
T6	Diafenthiuron 50 WP(FS)+ Castor oil @ 0.05	0.210g a.i/Plot 0.15 ml/Plot	16.73 (4.14)	1.75 (1.48)	1.26 (1.32)	2.06 (1.52)	1.69	86.99	16.88 (4.16)	1.74 (1.48)	1.43 (1.38)	1.66 (1.42)	1.61	87.61
T7	Diafenthiuron 50 WP (FS)+ Castor oil, Diafenthiuron (SS)	0.210g a.i/Plot 0.15 ml/Plot	15.43 (3.98)	1.68 (1.29)	1.60 (1.38)	0.64 (1.02)	1.13	91.26	15.81 (3.96)	1.31 (1.34)	1.13 (1.26)	1.04 (1.21)	1.16	91.07
	CD at 0.05%		.269	.397	.345	.673			.279	.256	.270	.500		
	SEm±		.924	.136	.118	.230			.958	.880	.926	.171		
	F value		ns	**	**	**			ns	**	**	**		

ST: Seed Treatment, FS: Foliar spray after 85 % emergence, SS: Second spray, H: Hours, ROC: Reduction over control

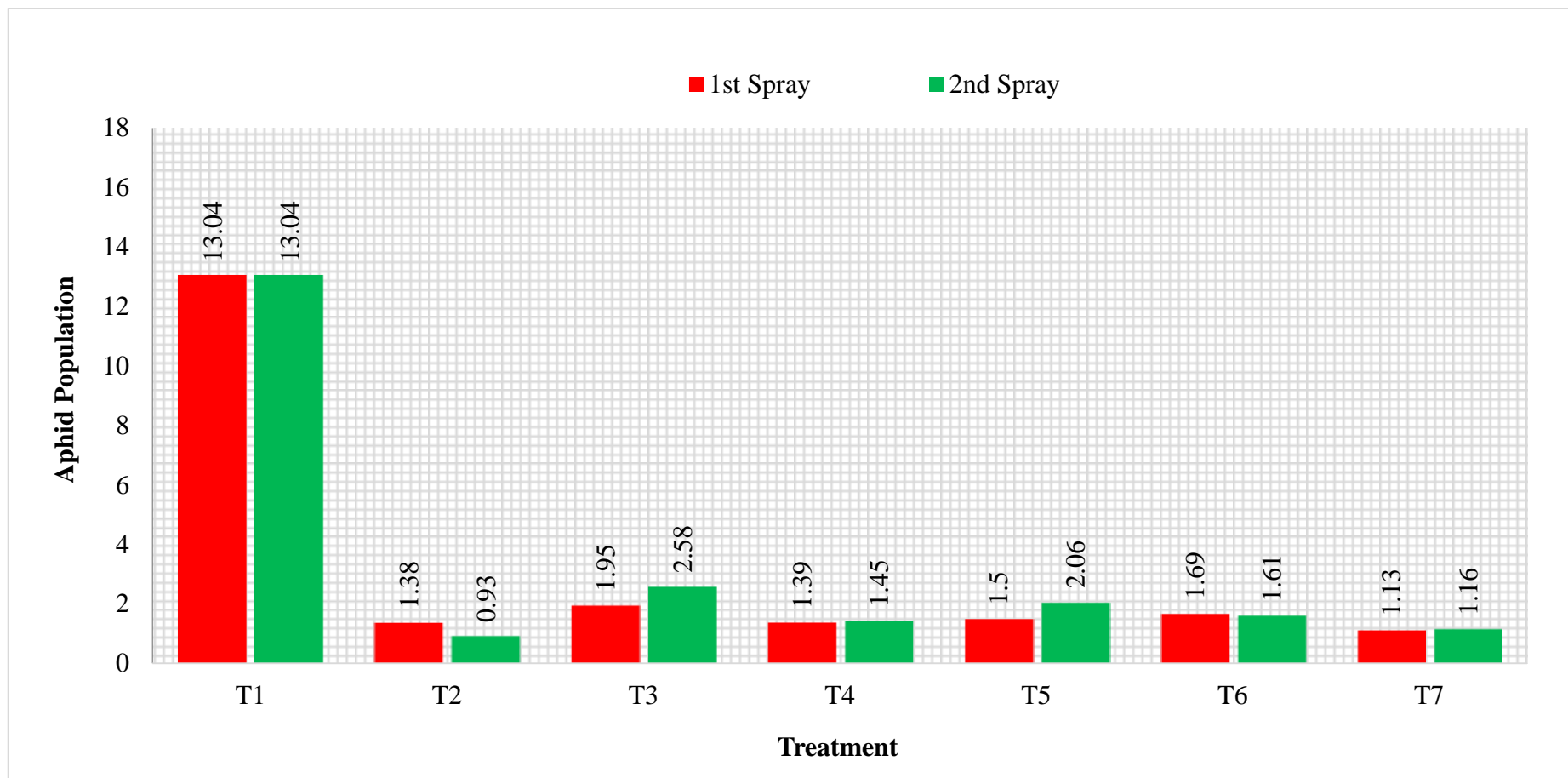


Fig 4.13. Efficacy of different insecticides foliar spray and seed treatment against aphid (2018-19)

After 24 hours of application minimum number of aphid population, 1.29 aphid/3 leaves) has been observed in T₂ followed by 1.31 aphid/3 leaves in T₇, 1.74 aphid/3 leaves in T₆, 1.79 aphid/3 leaves in T₄, 1.99 aphid/3 leaves in T₅ and 2.57aphid/3 leaves in T₃, however, the *Myzus persicae* population in all the treatments was significantly less than untreated control (12.87 aphid/3 leaves).

After 48 hours of application minimum number of whitefly population, 0.82 aphid/3 leaves has been observed in T₂ followed by 1.13 aphid/3 leaves in T₇, 1.34 aphid/3 leaves T₃, 1.43 aphid/3 leaves in T₆, 1.77 aphid/3 leaves in T₅ and 2.82 aphid/3 leaves in T₃, however, the aphid, *Myzus persicae* population in all the treatments was significantly less than untreated control (12.08 aphid/3leaves). Same trend has been observed on 72 hours of spray.

On the basis of overall mean population, T₂ was most effective treatment followed by T₇, T₄,T₆, T₅, and T₃

It was concluded that treatment T₂ which includes the application of Seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar spray of imidacloprid @60 g a.i./ha at 85% emergence + second spray with thiamethoxam 25 WG @ 100g a.i./ha was most promising treatment as they recorded minimum population after two sprays, followed by other treatments and untreated check.

Misra (2002) found that imidacloprid, as well as thiamethoxam, proved significantly superior in controlling aphids and jassids. **Aref (2011)** found that thiamethoxam and imidacloprid were the most effective against cotton aphids under field conditions. In contrast to our findings, **El-Zahi (2005)** reported that imidacloprid proved to be the most effective against aphids causing a 98.17% reduction as the general mean of the effect. **El-Dewy (2006)** mentioned that imidacloprid (confidor) proved to be a superior compound against aphids, jassids, and whitefly (adult). **Preetha at el, (2009)**. There was a hundred per cent mortality of aphids up to 7 days in the higher dose of imidacloprid i.e. 50 g a.i. ha⁻¹ and 25 g a.i. ha⁻¹ of imidacloprid and thiamethoxam at 25 g a.i. ha⁻¹, and order of relative efficacy of the insecticides based on the persistent toxicity index was as follows: imidacloprid at 50 g a.i. ha⁻¹ > imidacloprid at 25 g a.i ha⁻¹ > imidacloprid at 25 g a.i. ha⁻¹ > thiamethoxam at 25 g a.i. ha⁻¹ > imidacloprid at 15 g a.i. ha⁻¹ > methyl demeton at 125 g a.i. ha⁻¹

4.11.3. Efficacy of various treatments on the population of hopper (*Empoasca devastans*) during crop season 2018-19

The periodical data on population of hopper were recorded on potato one day before and 24, 48 and 72 hours days after each application during the cropping season 2018-19 is presented below:

Table 4.17 revealed that before first spray the mean population of hopper varied from 8.21 to 11.36 hopper/3 leaves, no significant difference was observed amongst treatment.

After 24 hours of application minimum number of hopper population, 1.07 hopper /3 leaves has been observed in T₂ followed by 1.15 hopper/3 leaves in T₅, 1.21 hopper/3 leaves in T₄, 1.32 hopper/3 leaves in T₆, 1.35 hopper/3 leaves in T₃ and 1.41 hopper/3 leaves in T₇, however the *Empoasca devastans* population in all the treatments was significantly less than untreated control (8.75 hopper/3 leaves).

After 48 hours of application minimum number of hopper population, 0.99 hopper /3 leaves) has been observed in T₂ followed by 1.58 hopper/3 leaves in T₇, 1.59 hopper/3 leaves in T₆, 1.89 hopper/3 leaves in T₅ and 2.07 hopper/3 leaves in T₃, however, the hopper population in all the treatments was significantly less than untreated control (9.24 hopper/3 leaves). Same trend has been observed on 72 hours of spray.

On the basis of overall mean population, T₅ was most effective treatment followed by T₄, T₇, T₂, T₃ and T₆.

Perusal at **table 4.17** indicated that before 2nd spray the mean population of hopper varied from 8.36 to 11.11 hopper/3 leaves, no significant difference was observed amongst treatment.

After 24 hours of application minimum number of hopper population, 1.19 hopper /3 leaves) has been observed in T₂ followed by 1.42 hopper/3 leaves in T₇, 1.32 hopper/3 leaves in T₄, 1.51 hopper/3 leaves in T₆, 1.99 hopper/3 leaves in T₅ and 2.19 hopper/3 leaves in T₃, however, the *Empoasca devastans* population in all the treatments was significantly less than untreated control (9.22 hopper/3 leaves).

Table 4.17: Efficacy of different insecticides foliar spray and seed treatment against green hopper (2018-19)

	Treatment	Dose	Pre-spray count	Hours after first spray			Mean	% ROC	Pre-spray count	Hours after second spray			Mean	% ROC
				24H	48H	72H				24H	48H	72H		
T1	Control	-	10.15 (3.23)	8.35 (2.97)	8.75 (3.03)	9.15 (3.09)	8.75	-	10.15 (3.25)	9.22 (3.11)	9.24 (3.10)	9.44 (3.14)	9.30	-
T2	Imidacloprid 200 SL (ST) + Imidacloprid @60 g a.i./ha(FS) + Thiamethoxam 25 WG (SS)	0.036g a.i/Plot 0.6g a.i/Plot	11.36 (3.42)	1.22 (1.31)	1.07 (1.18)	1.59 (1.43)	1.29	85.16	11.11 (3.40)	1.19 (1.30)	0.99 (1.18)	1.26 (1.32)	1.15	87.63
T3	Diafenthiuron 50 WP(FS)	0.210g a.i/Plot	10.08 (3.24)	1.49 (1.40)	1.35 (1.35)	1.16 (1.17)	1.33	84.75	10.84 (3.36)	2.19 (1.63)	2.07 (1.59)	2.16 (1.61)	2.14	76.91
T4	Diafenthiuron 50 WP (FS) + Diafenthiuron 50 WP (SS)	0.210g a.i/Plot	8.31 (2.95)	1.38 (1.36)	1.21 (1.30)	1.07 (1.18)	1.22	86.04	8.58 (3.05)	1.32 (1.34)	1.32 (1.35)	1.47 (1.39)	1.37	85.21
T5	Castor oil @ 0.05(FS)	0.15 ml/Plot	9.44 (3.15)	1.12 (1.24)	1.15 (1.25)	1.16 (1.26)	1.14	86.86	10.21 (3.27)	1.99 (1.57)	1.89 (1.53)	1.14 (1.28)	1.67	81.97
T6	Diafenthiuron 50 WP(FS)+ Castor oil @ 0.05	0.210g a.i/Plot 0.15 ml/Plot	8.21 (2.93)	1.27 (1.33)	1.32 (1.34)	1.76 (1.48)	1.45	83.38	9.60 (3.15)	1.51 (1.41)	1.59 (1.44)	1.66 (1.46)	1.59	82.88
T7	Diafenthiuron 50 WP (FS)+ Castor oil, Diafenthiuron (SS)	0.210g a.i/Plot 0.15 ml/Plot	9.27 (3.10)	1.28 (1.33)	1.41 (1.37)	1.26 (1.32)	1.32	84.89	8.36 (2.96)	1.42 (1.38)	1.58 (1.43)	1.55 (1.41)	1.52	83.65
	CD at 0.05%		.411	.188	.313	.392			.369	.158	.246	.243		
	SEm±		.140	.645	.107	.134			.126	.542	.945	.835		
	F value		ns	**	**	**			ns	**	**	**		

ST: Seed Treatment, FS: Foliar spray after 85 % emergence, SS: Second spray, H: Hours, ROC: Reduction over control

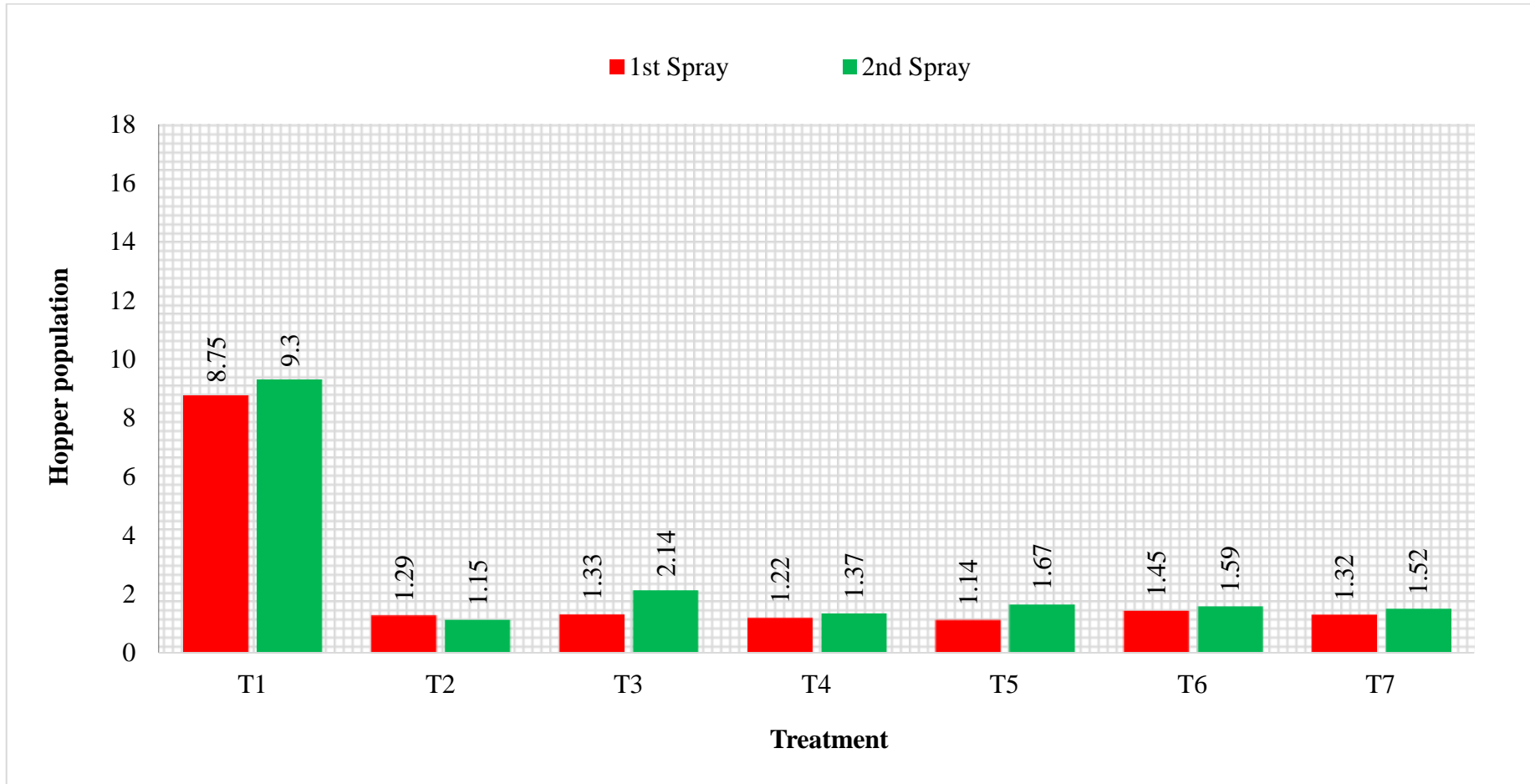


Fig 4.14. Efficacy of different insecticides foliar spray and seed treatment against green hopper (2018-19)

After 48 hours of application minimum number of hopper population, 0.99 hopper /3 leaves) has been observed in T₂ followed by 1.32 hopper/3 leaves in T₄, 1.58 hopper/3 leaves T₇, 1.59 hopper/3 leaves T₆, 1.89 hopper/3 leaves in T₅ and 2.07hopper/3 leaves T₃, However the hopper population in all the treatments was significantly less than untreated control (9.24 hopper/3leaves). Same trend has been observed on 72 hours of spray.

On the basis of overall mean population, T₂ was most effective treatment followed by T₃, T₄, T₇, T₆ and T₅

It was concluded that treatment T₂ which includes the application of seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar spray of imidacloprid @60 g a.i./ha at 85% emergence + second spray with thiamethoxam 25 WG @ 100g a.i./ha was most promising treatment as they recorded minimum population after two sprays, followed by other treatments and untreated check.

It is available in different formulations *viz.*, WG, FS, WS, and SL. imidacloprid @ 3 g/kg of seed, when mixed with polymer @ 40 ml/kg, provided good control against okra jassids and fruit borer **Satpathy et al. (2010)**. As foliar spray the recommended dose is 20-25 g a.i./ha, for seed treatment the dose is @ 3.5-7 g/kg seed and as seedling root dip the dose is 0.02-0.03% solution in okra **Satpathy and Kumar, (2010)** chili, brinjal and tomato. **Preetha et al. (2009)**, per cent mortality of leafhoppers was observed up to 9 DAT was the higher dose of imidacloprid at 50 g a.i. ha⁻¹ and up to 7 DAT in the recommended dose of imidacloprid, standard check Tatamida and thiamethoxam at 25 g a.i. ha⁻¹

4.11.4. Efficacy of various treatments on the population of thrips (*Thrips palmi*) during crop season 2018-19

The periodical data on population of thrips were recorded on potato one day before and 24, 48 and 72 hours days after each application during the cropping season 2018-19 is presented below:

It has been observed after perusal of **table 4.18** that before first spray the mean population of thrips varied from 13.18 to 15.14 thrips/3 leaves, no significant difference was observed amongst treatment.

Table 4.18 Efficacy of different insecticides foliar spray and seed treatment against thrips (2018-19)

Treatment	Dose	Pre - spray count	Hours after first spray			Mean	% ROC	Pre- spray count	Hours after second spray			Mean	% ROC	
			24H	48H	72H				24H	48H	72H			
T1	Control	-	13.39 (3.71)	12.19 (3.54)	12.79 (3.63)	13.59 (3.73)	12.86	-	12.77 (3.64)	11.82 (3.50)	11.99 (3.53)	13.80 (3.77)	12.54	-
T2	Imidacloprid 200 SL(ST) + Imidacloprid @60 g a.i./ha (FS) + Thiamethoxam 25 WG (SS)	0.036g a.i/Plot 0.6g a.i/Plot	15.14 (3.95)	1.62 (1.39)	1.31 (1.34)	1.39 (1.36)	1.44	88.78	15.04 (3.93)	1.20 (1.30)	1.32 (1.35)	1.28 (1.33)	1.27	89.84
T3	Diafenthiuron 50 WP(FS)	0.210g a.i/Plot	14.74 (3.89)	1.06 (1.17)	1.27 (1.33)	1.19 (1.25)	1.19	90.82	13.82 (3.77)	2.36 (1.66)	2.08 (1.60)	2.15 (1.61)	2.20	82.45
T4	Diafenthiuron 50 WP (FS) + Diafenthiuron 50 WP (SS)	0.210g a.i/Plot	14.56 (3.86)	2.05 (1.53)	2.35 (1.62)	1.21 (1.30)	1.21	85.44	15.50 (3.97)	1.92 (1.55)	1.78 (1.50)	1.38 (1.37)	1.69	86.45
T5	Castor oil @ 0.05(FS)	0.15 ml/Plot	14.18 (3.82)	1.32 (1.34)	1.97 (1.55)	1.63 (1.45)	1.63	87.22	14.45 (3.86)	2.50 (1.71)	2.19 (1.63)	2.34 (1.68)	2.34	81.26
T6	Diafenthiuron 50 WP(FS)+ Castor oil @ 0.05	0.210g a.i/Plot 0.15 ml/Plot	13.96 (3.80)	1.41 (1.35)	1.21 (1.30)	1.62 (1.39)	1.62	88.98	14.7 (3.89)	1.40 (1.37)	1.82 (1.52)	1.57 (1.43)	1.59	87.24
T7	Diafenthiuron 50 WP (FS)+ Castor oil, Diafenthiuron (SS)	0.210g a.i/Plot 0.15 ml/Plot	13.18 (3.69)	2.59 (1.73)	1.36 (1.29)	1.15 (1.17)	1.15	86.75	13.62 (3.74)	1.38 (1.36)	1.40 (1.37)	1.46 (1.39)	1.41	88.70
	CD at 0.05%		.370	.549	.416	.481			.332	.269	.186	.212		
	SEm±		.126	.188	.142	.164			.114	.923	.638	.728		
	F value		ns	**	**	**			Ns	**	**	**		

ST: Seed Treatment, FS: Foliar spray after 85 % emergence, SS: Second spray, H: Hours, ROC: Reduction over control

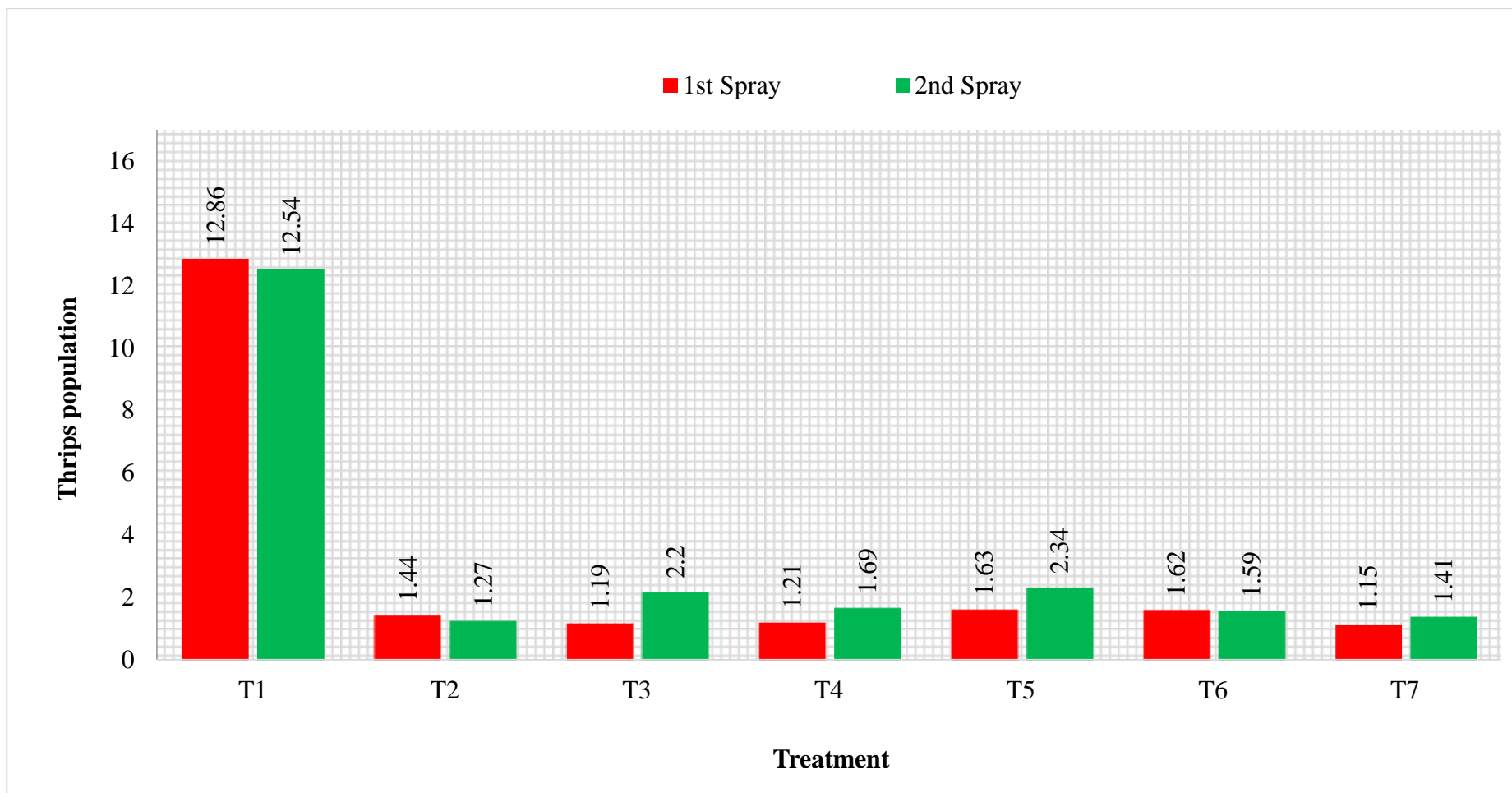


Fig. 4.15. Efficacy of different insecticides foliar spray and seed treatment against thrips (2018-19)

After 24 hours of application minimum number of thrips population, 1.06 thrips /3 leaves) has been observed in T₃ followed by 1.32 thrips/3 leaves in T₅, 1.41thrips/3 leaves in T₆, 1.62 thrips/3 leaves in T₂, 2.05 thrips/3 leaves in T₄ and 2.59 thrips/3 leaves in T₇, however the thrips population in all the treatments was significantly less than untreated control (12.19 thrips/3 leaves).

After 48 hours of application minimum number of thrips population, 1.28 thrips /3 leaves has been observed in T₆ followed by 1.27 thrips/3 leaves in T₃, 1.31 thrips/3 leaves T₂, 1.36 thrips/3 leaves in T₇, 1.97 thrips/3 leaves in T₅, 2.35 thrips/3 leaves in T₄, however, the thrips population in all the treatments was significantly less than untreated control (12.79 thrips/3 leaves). Same trend has been observed on 72 hours of spray.

On the basis of overall mean population, T₇ was most effective treatment followed by T₃, T₄, T₂, T₆ and T₅.

Perusal at **table 4.18** indicated that before 2nd spray the mean population of thrips varied from 12.77 to 15.50 thrips /3 leaves, no significant difference was observed amongst treatment.

After 24 hours of application minimum number of thrips population, 1.20 thrips /3 leaves) has been observed in T₂ followed by 1.38 thrips/3 leaves in T₇, 1.40 thrips/3 leaves in T₆, 1.92 thrips/3 leaves in T₄, 2.36 thrips/3 leaves in T₃ and 2.50 thrips/3 leaves in T₅, however the Thrips (*Thrips palmi*) population in all the treatments was significantly less than untreated control (11.82 thrips/3 leaves).

After 48 hours of application minimum number of thrips population, 1.32 thrips /3 leaves) has been observed in T₂ followed by 1.40 thrips/3 leaves in T₇, 1.78 thrips/3 leaves in T₄, 1.82 thrips/3 leaves in T₆, 2.08 thrips/3 leaves in T₃ and 2.19 thrips/3 leaves in T₅, however the thrips population in all the treatments was significantly less than untreated control (11.99 thrips/3leaves).

Same trend has been observed on 72 hours of spray.

On the basis of overall mean population, T₂ was most effective treatment followed by T₇, T₆, T₄, T₃, and T₅.

It was concluded that treatment T₂ which includes the application of seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar spray of imidacloprid @60 g a.i./ha at 85% emergence + second spray with thiamethoxam 25 WG @ 100g a.i./ha was most promising treatment as they recorded minimum population after two sprays, followed by other treatments and untreated check..

Santharam *et al.* (2003). Seed treatment of imidacloprid 70 WS at 10, 20 and 30g kg⁻¹ protected the seedlings in the nursery up to 45 days. The root dip of the seedlings before transplanting had no effect on the thrips population. Foliar treatment of imidacloprid 200 SL at 250, 375 and 500 ml ha⁻¹ reduced the thrips population significantly **Koenig *et al.* (2001)** Confidor (imidacloprid) effectively controlled cotton thrips. The results of the present studies are favored by the results of who determined that Actara 25 WG proved an excellent controlling agent against thrips. **Abbas *et al.* (2012)** All evaluated insecticides, Crown, Actara and Asualt, 24 h after application, have shown excellent performance against thrips on all cotton varieties. Among insecticides crown proved to be highly effective with more than 90% population reduction on varieties B.H.163 and V.H. 159. **Kukvaya *et al.* (2018)** the treatment imidacloprid 17.8 SL @ 0.005 per cent found most effective with lowest population of thrips and it was found at par with thiamethoxam 25 WG @ 0.008 percent. **El-Naggar, *et al.* (2013)** it is obvious that imidacloprid and thiamethoxam induced a fast initial effect. The reduction in the thrips population was 91.3 and 87.5% for imidacloprid, and 88.06 and 81.5% for thiamethoxam, in the 2010 and 2011 seasons, respectively.

4.12. Effect of different insecticide on yield of potato as foliar spray and seed treatment during crop season 2018- 2019

Seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar spray of imidacloprid @60 g a.i./ha at 85% emergence + second spray with thiamethoxam 25 WG @ 100g a.i./ha (41.63 T/ha), foliar spray of diafenthiuron 50 WP 350 g a.i. at 85% emergence followed by second spray of diafenthiuron after 10 days (40.00 T/ha), foliar spray of diafenthiuron 50 WP 350 g a.i. at 85% emergence (37.67 T/ha), foliar spray of diafenthiuron 50 WP 350 g a.i. at 85% emergence mixed with castor oil @0.05% by second spray with diafenthiuron after 10 days (36.00 T/ha), foliar spray of diafenthiuron 50 WP 350 g a.i at 85% emergence mixed with castor oil @ 0.05%

(35.00T/ha), foliar spray of castor oil @ 0.05% at 85% emergence (33.33T/ha). Lowest tuber yield (18.6 T/ha) on the contrary was recorded with control plot. Highest percent increase in yield over control (34.41%) was recorded in plots treated with seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar spray of imidacloprid @60 g a.i./ha at 85% emergence + second spray with thiamethoxam 25 WG @ 100g a.i./ha.

Table 4.19: Effect of different insecticidal foliar spray and seed treatment on yield of potato (2018-19)

Treatment		Dose	Yield of marketable fruits		
			Kg/plot	T/ha	% Increase over control
T1	Control	-	18.6	31.00	-
T2	Imidacloprid 200 SL(ST) + Imidacloprid @60 g a.i./ha(FS) + Thiamethoxam 25 WG (SS)	0.036g a.i/Plot 0.6g a.i/Plot	25	41.67	34.41
T3	Diafenthiuron 50 WP(FS)	0.210g a.i/Plot	22.6	37.67	21.51
T4	Diafenthiuron 50 WP (FS) + Diafenthiuron 50 WP (SS)	0.210g a.i/Plot	24	40.00	29.03
T5	Castor oil @ 0.05(FS)	0.15 ml/Plot	20	33.33	7.51
T6	Diafenthiuron 50 WP(FS)+ Castor oil @ 0.05	0.210g a.i/Plot 0.15 ml/Plot	21	35.00	12.90
T7	Diafenthiuron 50 WP (FS)+ Castor oil, Diafenthiuron (SS)	0.210g a.i/Plot 0.15 ml/Plot	21.6	36.00	16.12
	SEm±	-	1.467	-	-
	CD at 0.5%	-	2.23	-	-
	C.V.		7.448		

ST: Seed Treatment, FS: Foliar spray after 85 % emergence, SS: Second spray, H: Hours, Kg: Kilogram, T: Tone, ha: Hectare

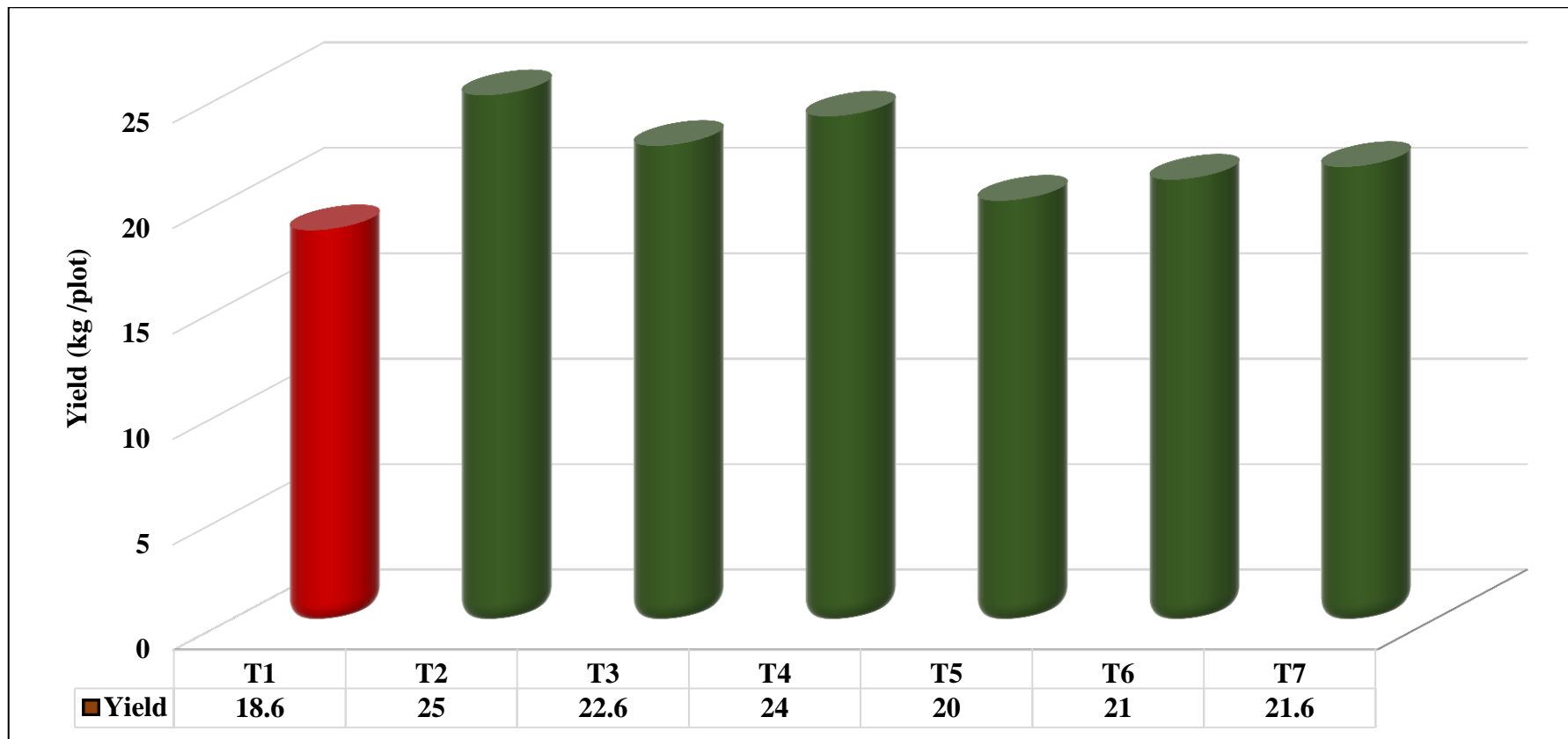


Fig 4.16.: Effect of different insecticidal spray and seed treatment on yield of potato (2018-19)



*Summary
and
Conclusions*



The experiments on various aspects of the present study entitled “**Management of insect pests of potato with some novel insecticides**” were conducted during *rabi* 2018-19. In the present investigation, field studies were conducted at the experimental area of Vegetable Research Center (VRC), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar (Uttarakhand).

The results are summarized under the following three heads:

1. To study seasonal incidence of various insect pests and mite in potato crop in *Tarai* region of Uttarakhand.
2. Comparison of imidacloprid and flonicamid against insect pests of potato.
3. Bioefficacy of some novel insecticides as foliar spray and seed treatment against insect pests of potato.

In the present investigation, the study revealed that the sucking pests like aphid, *Myzus persicae*, whitefly, *Bemisia tabaci*, thrips, *Thrips palmi* and leafhopper, *Empoasca devastans* were the major insect pests of the potato crop.

The activity of all these insect pests commenced from 4th week of November on potato variety Kufri Surya causing damage at various stages of the crop and remained active almost up to full growth of the crop. The activity of leafhopper (*Empoasca devastans*) initiated in the 3rd week of November with peak in third week of January with 5.43 nymphs and adults per plant with seasonal mean of 1.61 per plant. The density of whitefly reached its peak population of 1.51 to 15.46 per plant during the 3rd week of November and 4th week of January with seasonal mean of 5.34 per plant. The population of thrips recorded its peak density of 2.20 to 18.80 per plant during 3rd week of December with a seasonal mean of 4.58 per plant. The aphid recorded its peak activity of 0.84 to 12.13 per plant during last week of November with a seasonal mean of 6.66 aphids per plant.

Natural enemy's *viz.*, ladybird beetle and staphylinid beetle made their appearance on the crop in the last week of November and spiders made their first

appearance on crop in the 4th of November. The density of ladybird beetle increased gradually with peak population of 0.04 to 0.56 per plant during 2nd week of February with a seasonal mean of 0.20 ladybird beetle per plant. The staphylinid beetle recorded its peak population of 0.60 per plant during last week of January with a seasonal mean of 0.27 staphylinid beetle per plant. The activity of Spider increased gradually with peak activity of 0.12 to 0.56 per plant during last week of November with a seasonal mean of 0.25 spiders per plant.

Among the predators, ladybird beetles like *Menochilus sexmaculata*, *Coccinella septempunctata*, *Brymoides suturalis* and a spider, *Neoscona* sp. were observed preying on whiteflies, aphid, thrips, and leafhopper. Another spider, *Oxyopes* sp. and *Tetranychus*. and a predatory staphylinid beetle, *Paederus dermatitis* were observed feeding on whitefly, aphid and leafhopper. Correlation studies were worked out between the population of predators and that of sucking pests to see the effect of predators on the activity of the insect pests. There existed a significant positive correlation between aphids, thrips and predator ladybird beetle with “r” values 0.714**, 0.66* respectively. The regression equation between the pests and predators was as follows: $Y = 0.129x - 0.233$ $R^2 = 0.509$, $Y = 0.084 x_s + 0.244$ $R^2 = 0.437$

Comparative studies of two chemicals were conducted for their efficacy against major pest of potato, of these, flonicamid 50 WG @ 3gm /10 lits with repeat 15 days after 1st spray was found as the more effective than Imidacloprid insecticides against aphids (*Myzus persicae*), whitefly (*Bemesia tabaci*), jassid (*Empoasca devastans*) followed by other treatments.

After perusing the yield data it was observed that potato tuber yield was maximum (41 t/ha) in flonicamid 50 WG @ 3g /10 lits + repeat at 15 days with 34.41 percent increase over control.

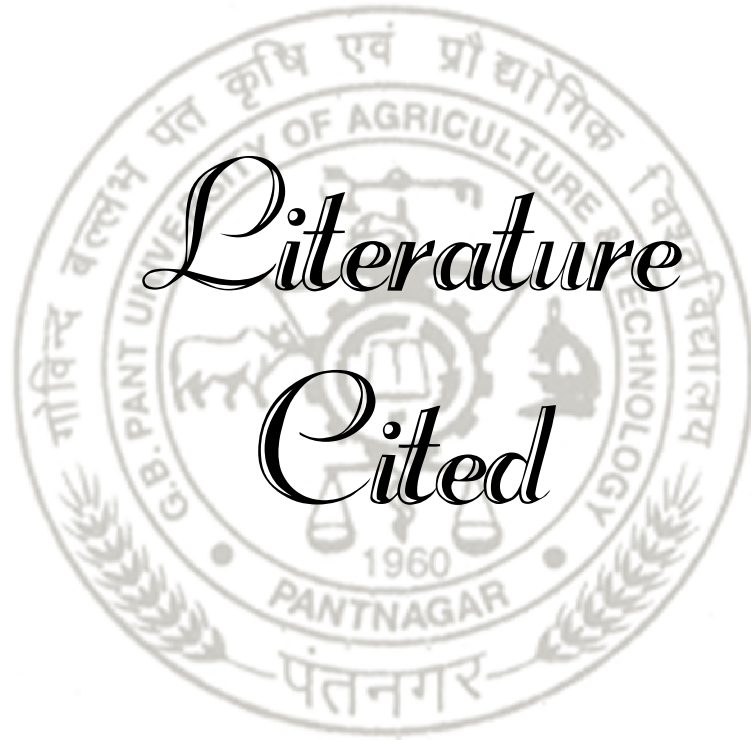
The effect of various treatments on natural enemies (spider, coccinellids) conclude that flonicamid 50 WG@3gm/10 lits appeared to be the safest treatment with single spray, however more spray resulted in mortality of natural enemies.

While studying the bioefficacy various insecticide it has been observed that Seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar Spray of imidacloprid @60 g a.i. /ha at 85% emergence and repeated second spray with

thiamethoxam 25 WG @ 100g a.i. /ha was most effective against potato insect pest like aphid (*Myzus persicae*), whitefly (*Bemesia tabaci*), jassid (*Empoasca devastans*) followed by Diafenthiuron as compared to other treatments castor oil could not manage the insect pests.

It was concluded that application of flonicamid 50 WG @ 3g /10 lits + repeat at 15 days after attaining the pest population at economic threshold label effectively managed the sucking pests population and seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar Spray of imidacloprid @60 g a.i./ha at 85% emergence + second spray with thiamethoxam 25 WG @ 100g a.i./ha was also effective against sucking insect pests but while comparing the flonicamid and imidacloprid it has been observed that flonicamid was more effective as compared to imidacloprid.

It has been noticed that injudicious and indiscriminate use of imidacloprid in vegetable agro ecosystem leads to heavy contamination of vegetable crops and ill effects on beneficial organism. Flonicamid could be a good alternative of the imidacloprid for managing insect pests of potato due to its less toxicity against natural enemies. Timely application of chemicals in potato crop may be very much beneficial to farmers as every insect pests have its own threshold level for the crop however alternate use of different group of chemicals with some botanicals may check the development of resistance and resurgence of insect pests. In present investigation it has been observed that novel molecule of flonicamid can be useful in management of potato alone or in combination.



*Literature
Cited*



LITERATURE CITED

- Abbas, Q., Arif, M. J., Gogi, M. D., Abbas, S. K. and Karar, H. 2012.** Performance of imidacloprid, thiamethoxam, acetamiprid and a bio control agent (*Chrysoperla carnea*) against whitefly, jassid and thrips on different cotton cultivars. *World Journal of Zoology*, 7(2): 141-146.
- Ahmad, M., Hussain, S. I., Khokar, K. M., Jeelani, G. and Mahmood, T. 1986.** Population dynamic of leaf hopper (*Amrasca biguttula biguttula*) on brinjal and effects of abiotic factors on its dynamics. *Asian Journal of Plant Sciences*, 4, 403-404.
- Ahmed, S., Nisar, M. S., Shakir, M. M., Imran, M and Iqbal, K. 2014.** Comparative efficacy of some neonicotinoids and traditional insecticides on sucking insect pests and their natural enemies on *Bt-121* cotton crop. *Journal of Animal and Plant Sciences*. 24(2): 660-663.
- Ali, F., Badshah, H., Rehman, A. and Shah, A. 2004.** Population density of cotton whitefly *Bemisia tabaci* and mites *Tetranychu surticae* on brinjal and their chemical control. *Asian Journal of Plant Sciences* 3 (5): 589-592.
- Amoakwah, E., Judith, F. M., and Essumang D. K., 2013.** Assessing the efficacy of imidacloprid 20% SL as an insecticide against aphids in cultivated okra plants in a tropical ecosystem: a case study of mampongeng Kumasi, Ghana for the 2011 and 2012 cropping period. *Journal of Science and Technology* 3(4): 390-395.
- Anonymous, 2011.** Agriculture Statistics at a Glance. Directorate of Economics and Statistics, Ministry of Agriculture, *Govt. of India*.
- Aref, S. A. and El-Zahi, S. E. 2011.** Field evaluation of recommended insecticides to control bollworms on cotton aphid, *Aphis gossypii* glover and their side effect on associated predators. *Journal of Pest Control and Environmental Sciences*, 19(1): 55-68.
- Asi M. R., Afzal M., Anwar S. A., Bashir M. H. 2008.** Comparative efficacy of insecticides against sucking insect pests of cotton. *Pakistan Journal of Life and Social Sciences* 6 (2): 40-142.

- Bajya, D. R., Ranjith, M., Lakharan, M. C. and Raza, S. K. 2016.** Efficacy of diafenthiuron 47.8 SC against sucking pests of cotton and its safety to natural enemies. *Indian Journal of Entomology*, 78(1): 15-23.
- Bambhaniya, V. S., Khanpara, A. V. and Patel, H. N. 2018.** Bio-Efficacy of insecticides against sucking pests; Jassid and Thrips infesting tomato. *Journal of Pharmacognosy and Phytochemistry*, 7(3): 1471-1479.
- Bartual, J. Lozoya, A. Garcia, J. Valdes, G. 2012.** Efficacy and residues of selected insecticides for control of cotton aphid (*Aphis gossypii*) and mealybug (*Planococcus citri*) in pomegranates. *Options Mediterraneennes. Serie A, Seminaires Mediterraneens. (103)*: 107-111.
- Bhadauria, N. S., Bhadauria, N. K. S. and Jakhmola, S. S. 1997.** Incidence of potato aphids (*M. persicae*) on the crop planted on different dates. *Bhartiya-Krishi-Anusandhan-Prika*, 12(2): 95-98.
- Bharadiya, H. A., Patil, G. S. 2005.** Influence of abiotic factors on population development of *Bemisia tabaci* infesting *Abelmoschus esculentus*. *International Research Journal of Plant Science*, 3(2): 012-018.
- Bharpoda, T. M., Patel, N. B., Thumar, R. K., Bhatt, N. A., Ghetiya, L.V., Patel, H. C. and Borad, P. K. 2014.** Evaluation of insecticides against sucking insect pests infesting *Bt* cotton BG- II. *The Bioscan*, 9(3): 977- 980.
- Bhatnagar, Anuj 2007.** Incidence and succession of thrips, leafhoppers, and whitefly in combination of planting dates and potato varieties. *Annals of Plant Protection Sciences*, 15: 101-105.
- Bijjur, S. and Verma, S. 1996.** Effect of abiotic factors on the pests of pea and natural enemies. *Indian Journal of Entomology*, 57(3): 233-239.
- Brown, C. R. 2005).** Antioxidants in potato. *American Journal of Potato Research*, 82(2): 163-172.
- Butani, D. K. and Jotwani, M. G. 1983.** Insects as a limiting factor in vegetable production. *Pesticides*, 17 (9): 6-13.
- Butani, D.K. and Jotwani, M.G. 1984.** Insects in Vegetables. *Colour Publications*, Mumbai, India; 47-50.

- Chandi, R. S., Kumar, V., Bhullar, H. S., and Dhawan, A. K. 2016.** Field efficacy of flonicamid 50 WG against sucking insect pests and predatory complex on *Bt* cotton. *Indian Journal of Plant Protection*, 44(1): 1-8.
- Chandel, R.S., Dhiman, K. R., Chandla, V. K., and Kumar, V. 2007.** Integrated pest management in potato. In: Jain, P.C., Bhargava, M.C. (Eds.): *Entomology: Novel Approaches in Entomology*, New India Publishing Agency, New Delhi, India, . 377–398.
- Chaudhuri, N., Deb, D. C. and Senapati, S. K. 2001.** Assessment of loss in yield caused by pest complex of tomato under terai region of West Bengal. *Crop Research*, 2(1): 71-79.
- Chinniah, C. and Ali, K. A. 2000.** Relative efficacy of insecticides/acaricidal against sucking pests of okra. *Pest Management and Economic Zoology*, 8(2): 111-116.
- Cho, S. R., Koo, H. N., Yoon, C. and Kim, G. H. 2011.** Sublethal effects of flonicamid and thiamethoxam on green peach aphid, *Myzus persicae* and feeding behavior analysis. *Journal of the Korean Society for Applied Biological Chemistry*, 54(6): 889-898.
- Dahatonde, J. A., Pandya, H. V., Raut, S. B. and Patel, S. D. 2014.** Seasonal abundance of jassid and whitefly on brinjal (*Solanum melongena* L.) in relation to major abiotic factors. *International Journal of Plant Protection*, 7(1): 257-259.
- Das, G. S. and Logiswaran, G. 2003.** Seasonal pattern of leafhopper and cotton aphid, occurrence on brinjal in terms of day of degree. *Journal of Andaman Science Association*, 13(1-2): 99-101.
- Elbert, A., Becker, B., Hartwig, J. and Erdelen, C. 1991.** Imidacloprid-a new systemic insecticide. *Pflanzenschutz-Nachrichten Bayer (Germany, FR)*.
- El-Dewy M. H. E. 2006.** *Toxicological studies on some pests attacking cotton*. Ph. D. Thesis, Fac. Agric., Kafr El-Sheikh Univ., Egypt, 101 pp.
- El-Naggar, J. B. and Zidan, N. E. H. A. 2013.** Field evaluation of imidacloprid and thiamethoxam against sucking insects and their side effects on soil fauna. *Journal of plant Protection Research*, 53(4): 375-387.

- El-Zahi S. E. 2005.** *Integrated management of some cotton pests*. Ph. D. Thesis, Fac. Agric., Mansoura Univ., Egypt, 174 pp.
- El-Zahi, S. E. and Aref, S. A. 2011.** Field evaluation of recommended insecticides to control bollworms on cotton aphid, *Aphis gossypii* Glover and their side effect on associated predators. *Journal of Pest Control and Environmental Sciences*. 19(1): 55-68
- FAOSTAT. 2017.** *Food and Agriculture organization of the united nation*. Retrieved from <http://www.fao.org/faostat/en/#search/potatoes>
- Fenigstein, A., Eliyahu, M., Gan-Mor, S. and Veierov, D. 2001.** Effects of five vegetable oils on the sweet potato whitefly *Bemisia tabaci*. *Phytoparasitica*, 29(3): 197-206.
- Fonseca, P. R. B., Fortunato, R. P., Lima, J., Bertocello, T. F. and Degrande, P. E. 2011.** Leaf, stem and root absorption of pymetrozine and flonicamid to control the cotton aphid *Aphis gossypii* Glover, 1877 (Hemiptera: Aphididae). *Arquivos do Instituto Biológico (São Paulo)*: 78(1): 123-127.
- Furiatti, R. S. and de Almeida, A. A. 1993.** Population fluctuation of the aphids *Myzus persicae* (Sulzer, 1778) and *Macrosiphum euphorbiae* (Thomas, 1878) (Hemiptera: Aphididae) and the relation with temperature. *Revista Brasileira de Entomologia*, 37(4): 821-826.
- Ghelani, M. K., Kabaria, B. B. and Chhodavadia, S. K. 2014.** Field efficacy of various insecticides against major sucking pests of *Bt* cotton. *Journal of Biopesticides*, 7: 27.
- Ghosal, A., Chatterjee, M. L. and Bhattacharyya, A. 2013.** Bio-efficacy of neonicotinoids against *Aphis gossypii* Glover of okra. *Journal of Crop and Weed*, 9(2): 181-184.
- Ghosh, S. K., Chakraborty, K. and Mandal, T. 2013.** Bio-ecology of predatory coccinellidbeetle, *Coccinella septempunctata* (Coleoptera: Coccinellidae) and its dynamics in rice field of *Tarai* region of West Bengal, India. *International Journal of Bio-resource and Stress Management*, 4(4): 571-575.

- Ghosh, S. K., Laskar, N. and Senapati, S. K. 2004.** Seasonal fluctuation of *Aphis gossypii* Glov. on brinjal and field evaluation of some pesticides against *A. gossypii* under *terai* region of West Bengal. *Indian Journal of Agricultural Research*, 38(3): 171- 177.
- Giordanengo, P., Vincent, C. and Alyokhin, A. 2013.** Insect Pest of Potato: Global perspectives on biology and management. Chapter 14: Donald C. Weber. *Biological Control of Potato Insect Pests*. Academic Press, pp. 418.
- Grandjean, F. 1948.** “Sur les Hydrozetes (Acari) de l’Europeooccidentale”. *Bul. Mus. Nat. Hist. Hat.* 19, Ser. 2, 395–402.
- Gupta, G. P., Agnihotri, N. P., Sharma, K. and Gajbhiye, V. T. 1998.** Bioefficacy and residue of imidacloprid in cotton. *Pesticide Research Journal*, 10(2): 149-154.
- Herbert, A. A., Katz, T. M. and Miller, J. H. 2008.** Insect repellents: historical perspectives and new developments. *Journal of the American Academy of Dermatology*, 58(5): 865-871.
- Horton, D. and Sawyer, R. L. 1985.** The Potato as a world crop with special referenc to developing areas. *Potato Physiology*, 1-34.
- Hughes, R. D. 1963.** Population dynamics of the cabbage aphid, *Brevicoryne brassicae* (L.). *The Journal of Animal Ecology*, 393-424.
- Jakhar B. L., Panickar, B., Ravindrababu, Y. 2012.** Management of whitefly, *Bemisia tabaci* (Gennadius) through seed treatment in moth bean. *Journal of Applied and Natural Science*, 8(2): 890-893.
- Jakhar, B. L., Panickar, B. and Ravindrababu, Y. 2016.** Management of white fly, *Bemisia tabaci* (Gennadius) through seed treatment in moth bean. *Journal of Applied and Natural Science*, 8(2): 890-893.
- Jalali, M.A., Leeuwen, T., van Tirry, L and Clercq, P. De. 2009.** Toxicity of selected insecticides to the two-spot ladybird, *Adalia bipunctata*. *Phytoparasitica*. 37(4): 323-326.
- Jansen, J. P., Defrance, T. and Warnier, A. M. 2011.** Side effects of flonicamid and pymetrozine on five aphid natural enemy species. *BioControl*, 56(5): 759-770.

- Jemec, A., Tisler, T., Drobne, D., Sepcic, K., Fournier, D. and Trebse, P. 2007.** Comparative toxicity of imidacloprid, of its commercial liquid formulation and of diazinon to a non-target arthropod, the microcrustacean *Daphnia magna*. *Chemosphere*, 68(8): 1408-1418
- Jeppson, L.R., Keifer, H. H. and Baker, E. W. 1975.** *Mites Injurious to Economic Plants*. University of California Press, Berkeley, 614 Pp.
- Jeschke, G. B., Loso, M. R., Babcock, J. M., Hasler, Letherer, T. J., Young, C. D., and Sparks, T. C. 2011.** Novel nicotinic action of the sulfoximine insecticide sulfoxaflor. *Insect Biochemistry and Molecular Biology*, 41(7): 432-439.
- Jha, S. K. and Kumar, M. 2018.** Fluctuation in whitefly *Bemisia tabaci* population in relation to environmental factors.
- Jones, D. R. 2005.** Plant viruses transmitted by thrips. *European Journal of Plant Pathology*, 113(2): 119-157.
- Kar, A. 2017.** Bioefficacy evaluation of imidacloprid 17.8% SL and thiamethoxam against whitefly on tomato and their effect on natural enemies. *Journal of Entomology and Zoology Studies*, 5(3): 1064-1067.
- Karmakar, R. and Kulshrestha, G. 2009.** Persistence, metabolism and safety evaluation of thiamethoxam in tomato crop. *Pest Management Science: formerly Pesticide Science*, 65(8): 931-937.
- Kashyap, R. K. and Verma, A. N. 1994.** New record of aphids infesting seed crop of potato. *Journal of Indian Potato Association* 9(2-3-4): 157-58.
- Kaur, C., George, B., Deepa, N., Singh, B. and Kapoor, H. C. 2004.** Antioxidan status of fresh and processed tomato. A review. *Journal of Food Science Technology* 41: 479-486.
- Khaire, V. M., Kachare, B. V. and Mote, U. N. 1992.** Efficacy of different vegetable oils as grain protectants against pulse beetle, *Callosobruchus chinensis* L. in increasing storability of pigeon pea. *Journal of Stored Products Research*, 28(3): 153-156.

- Khattak M. K., Shafqrat A., Chishti J. I., Saljki A. R., Hussain A. S. 2004.** Efficacy of certain insecticides against some sucking insect pests of mung bean (*Vigna radiata*). *Pakistan Entomologist*, 26 (1): 75–80.
- Kodandaram, M. H., Kumar, Y. B., Banerjee, K., Hingmire, S., Rai, A. B. and Singh, B. 2017.** Field bioefficacy, phytotoxicity and residue dynamics of the insecticide flonicamid (50 WG) in okra [*Abelmoschus esculenta* (L) Moench]. *Crop Protection*, 94, 13-19.
- Koenig, J.P., Lawson, N., Minton, K. Lovelace and Semipro, K. 2001.** Field trial results with pymerrozine and thiamethoxam for the control of pymerrozine and thiamethoxam for the control of aphid. Proceed., Beltwide Cotton Conf., San Antonio, USA, 2: 1335-1337.
- Kolhe, A. V., Nawod, S. S., Patil, B. R. and Ingole, O. V. 2009.** Bio-efficacy of newer insecticides against sucking pests of cotton. *Journal of Cotton Research and Development*, 23(1): 146-148.
- Konar, A. and Basu, A. 2000.** Buildup of aphids on potato in Hoogly district of West Bengal. *Potato, Global Research and Development*, 1: 477-479.
- Konar, A., Kiran, A. M. and Dutta, S. K. 2013.** Population dynamics and efficacy of some insecticides against aphid on okra. *Journal of Crop and Weed*, 9(2): 168-171.
- Konar, A., Singh, N. J., Mandal, P. and More, K. A. 2005.** Screening of potato germplasm against aphid and whitefly in gangetic plains of West Bengal. *Journal of the Entomological Research Society*, 37(3): 229-232.
- Koo, H. N., Lee, S. W., Yun, S. H., Kim, H. K. and Kim, G. H. 2015.** Feeding response of the cotton aphid, *Aphis gossypii*, to sublethal rates of flonicamid and imidacloprid. *Entomologia Experimentalis et Applicata*, 154(2): 110-119.
- Kukvaya, D., Jakhar, B. L., Chaudhari, S. J. and Patel, B. C. 2018.** Bio-efficacy of insecticides against sucking insect pests of moth bean, (*Vigna aconitifolia* Jacq.) Marechal. *Journal of Entomology and Zoology Studies*, 6(5): 2227-2230
- Kumar, K. and Santharam, G. 1999.** Effect of imidacloprid against aphids and leafhoppers on cotton. *Annals of Plant Protection Sciences*. 7 (2): 248 -250.

- Kumar, R. V. 2014.** “*Evaluation of certain cotton genotypes against sucking pests and their management with insecticides*” (Doctoral dissertation, Acharya NG Ranga Agricultural University).
- Kumawat, R. L., Pareek, B. L. and Meena, B. L. 2000.** Seasonal incidence of jassid and whitefly on okra and their correlation with abiotic factors. *Annals of biology*, 16(2): 167-169.
- Lakra, B. S. 2001.** Integrated management of whitefly, *Bemisia tabaci* (Gennadius) and potato apical leaf curl virus in India. *Potato research*, 53(2): 129-139.
- Lamp, W. O., Nielsen, G. R., Fuentes, C. B. and Quebedeaux, B. 2004.** Feeding site preference of potato leafhopper (Homoptera: Cicadellidae) on alfalfa and its effect on photosynthesis. *Journal of Agricultural and Urban Entomology*, 21(1): 25-38.
- Lobna T. M. Zidan. 2012.** Bio-Efficacy of three new neonicotinoid insecticides as seed treatment against four early sucking pests of *Cotton American*, *Journal of Agricultural and Environmental Sciences*.12 (4): 535-540.
- MAFW, 2019.** Horticulture Statistics Division Department of Agriculture, Cooperation and Farmers Welfare Ministry of Agriculture and Farmers Welfare. *Government of India New Delhi*
- Mahmood, T., Hussain, S., Khokhar, K. M., Jeelani, G. and Ahmad, M. 2002.** Population dynamics of leafhopper, *Amrasca biguttula biguttula* on brinjal and effects of abiotic factors on its dynamics. *Asian Journal of Plant Science* 1(4): 403-404.
- Mandloi, R. 2015.** Impact of weather factors on the incidence of major insect pests of tomato (*Solanum lycopersicon l.*) cv. H-86 (KashiVishesh). *The Ecoscan*, 7-12.
- Mathur, A., Singh, N. P., Meena, M. and Singh, S. 2012.** Seasonal incidence and effect of abiotic factors on population dynamics of major insect pests on brinjal crop. *Journal of Environmental Research and Development* 1(7): 53-55.
- Medina-Hernández, D., Vargas-Salinas, M., Rueda-Puente, E. O. and Holguín-Peña, R. J. 2019.** Seasonal Distribution of *Bemisia tabaci* (Hemiptera: Aleyrodidae) MEAM1 Species and Impact on Incidence of Begomoviral Diseases in Baja California Sur. *Journal of Economic Entomology*. 112(3): 1055-1061.

- Meena, N. K., Kanwat, P. M., Meena, A. and Sharma, J. K. 2010.** Seasonal incidence of jassids and white flies on okra, *Abelmoschus esculentus* (L.) Moench in semiarid region of Rajasthan. *Annals of Agri-bio Research* 15(1): 25-29.
- Meena, R. S., Ameta, O. P. and Meena, B. L. 2013.** Population dynamics of sucking pests and their correlation with weather parameters in chilli, *Capsicum annum* L. crop. *The Bioscan*, 8(1): 177-180.
- Meena, R. S., Ameta, O. P. and Meena, B. L. 2013.** Population dynamics of sucking pests and their correlation with weather parameters in chilli (*Capsicum annum*) Crop. *The Bioscan*, 8 (1): 177-180.
- Meena, R. S.; Ameta, O. P. and Meena, B. L. 2012.** Population dynamics of sucking pests and their correlation with weather parameters in brinjal Crop. *The Bioscan*, 8(1): 177-180.
- Metcalf, C. L. and Flint, W. P. 1978.** Destructive and Useful Insects and Their Habits and Control. McGraw Hill International Book Co. Singapore. 1087pp
- Misra H. P. 2002.** Field evaluation of some newer insecticides against aphids (*Aphis gossypii*) and jassids (*Amrasca biguttula*) on okra. *Indian Journal of Entomology*, 64(1): 80-84.
- Misra, S. S. 1995.** White grub, *Holotrichia* (*Lachnosterna*) *coracea* (Hope)-A key pest of potatoes in Himachal Pradesh (India). *Journal of Entomological Research*, 19(2): 181-182.
- Misra, H. P. 2009.** Safer novel insecticide molecule for the management of rice brown planthopper, *Nilaparvata lugens* (Stal.). *Indian Journal of Entomology*, 71(3): 232-235.
- Morita, M., Ueda, T., Yoneda, T., Koyanagi, T and Haga, T. 2007.** Flonicamid, a novel insecticide with a rapid inhibitory effect on aphid feeding. *Pest Management Science*. 63(10): 969-973.
- Morita, M., Yoneda, T., and Akiyoshi, N. 2014.** Research and development of a novel insecticide, flonicamid. *Journal of Pesticide Science*, 39(3): 179-180.
- Moschetti, R. 2003.** Biological control using beneficial insects. *Biol. Cont. Bul. IPM of Alaska*. www.ipmofalaska.com rocco@ipmofalaska.com.

- Muthukumar, M. and Kalyanasundaram. 2003.** Influence of abiotic factors on the incidence of major insect pests in Brinjal (*Solanum melongena* L.). *South India Horticulture*.51 (1-6): 214-218.
- Nag, D. 2016.** Seasonal incidence and management of major insect pests on *rabi* crop of potato at Raipur M.Sc. (Ag) Thesis1-130.
- Naggar, J. B. and Zidan, N. E. H. A. 2013.** Field evaluation of imidacloprid and thiamethoxam against sucking insects and their side effects on soil fauna. *Journal of Plant Protection Research*, 53(4): 375-387.
- Narang, S. K., Tabachnick, W. J. and Faust, R. M. 1983.** Complexities of population genetic structure and implications for biological control programs. *Applications of Genetics to Arthropods of Biological Control Significance*, 19-52.
- Nateghi, M., Paknejad, F. and Moarefi, M. 2014.** Effect of concentrations and time of Kaolin spraying on wheat aphid. *Journal of Environmental Biology*, 7(21): 163-168.
- Natick, E. T., Palumbo, J. C. and Engle, C. E. 1996.** Effects of imidacloprid on colonization of aphids and silver leaf whitefly and growth, yield and phytotoxicity in cauliflower. *Southwestern Entomologist*, 21: 283–292.
- Nauen, R. and Bretschneider, T. 2002.** New modes of action of insecticides. *Pesticide Outlook*, 13(6): 241-245.
- Nauen, R., Ebbinghaus-Kintscher U. L., Salgado, V. and Kausmann M. 2012.** Thiamethoxam is a neonicotinoids precursor converted to clothianidin in insects and plants. *Pestic. Biochem. Physiol.* 2003; 76(2): 55-69.
- Neergude, M., Biradar, A. P., Veerendra A. C. and Sathisha, R. 2014.** Seasonal abundance of onion thrips, *Thrips tabaci* Lindeman and their natural enemies under dry land conditions. *International Journal of Advances in Pharmacy Biology and Chemistry.*, 3(1): 33-36.
- NHB. 2018.** Horticulture statistics at glance. Ministry of agriculture and farmer welfare department of agriculture, cooperation and farmers welfare horticulture statistics division. *Govt. of India*

- Nieto, J. and Simonetta, F. 2008.** Whitefly control with soil applications of flonicamid (Teppeki 50 WG) on protected tomatoes. *Giornate Fitopatologiche*.14(1): 263-268.
- Nieto, J. and Simonetta, F. 2008.** Whitefly control with soil applications of flonicamid (Teppeki 50 WG) on protected tomatoes. *Giornate Fitopatologiche*.14 (1): 263-268. *Pakistan Journal of Agriculture and Agricultural Engineering and Veterinary Science*. 27 (2): 168-175.
- Oerke, E. C. and Dehne, H. W. 2004.** Safeguarding production-losses in major crops and the role of crop protection. *Crop protection*, 23(4): 275-285.
- Oommen, S. and Kumar, A. 2004.**Seasonal incidence of insect pests of potato. *Indian journal of Entomology*, 18 (1): 65-66.
- Pandey, R., Rai, M. K., Sharma, K. and Chaudhari, D. 2007.** Studies on population dynamics of *Myzus persicae* on potato crop with special reference to its relation with various weather parameters. *Journal of Vegetation Science*, 34(2): 167-169.
- Parker, W. E., 1997.** Forecasting the timing and size of the field population of aphids on potato in India. *Indian Journal of Agricultural Sciences*, 75 (1): 5-15.
- Patel, B. H., Koshiya, D. J. and Korat, D. M. 2009.** Population dynamics of chilli thrips, *Scirtothrips dorsalis* Hood in relation to weather parameters. *Karnataka Journal of Agricultural Sciences*, 22(1): 108-110.
- Patel, J. R., Bhalani, H.C. 1981.** Effect of weather parameters on brinjal Jassids, *Amrasca biguttula biguttula* (Ishida). *Gujarat Agricultural University Research Journal*, 19(2): 39-43.
- Patel, Y. and Patel, P. 2014.** A Study on Efficacy and Economics of Some Modern Insecticides against Jassid, *Amrasca biguttula biguttula* (Ishida) in Cotton. *Trends in Biosciences*, 7(10): 889-892.
- Pathipati, V. L., Vijayalakshmi, T. and Naidu, L. N. 2014.** Seasonal incidence of major insect pests of chili in relation to weather parameters in Andhra Pradesh. *Pest Management in Horticultural Ecosystems*, 20(1): 36-40.
- Pathipati, V. L., Vijayalakshmi, T. and Naidu, L.N. 2014.** Seasonal incidence of major insect pests of chilli in relation to weather parameters in Andhra Pradesh. *Pest Management in Horticultural Ecosystems*, 20(1): 36-40.

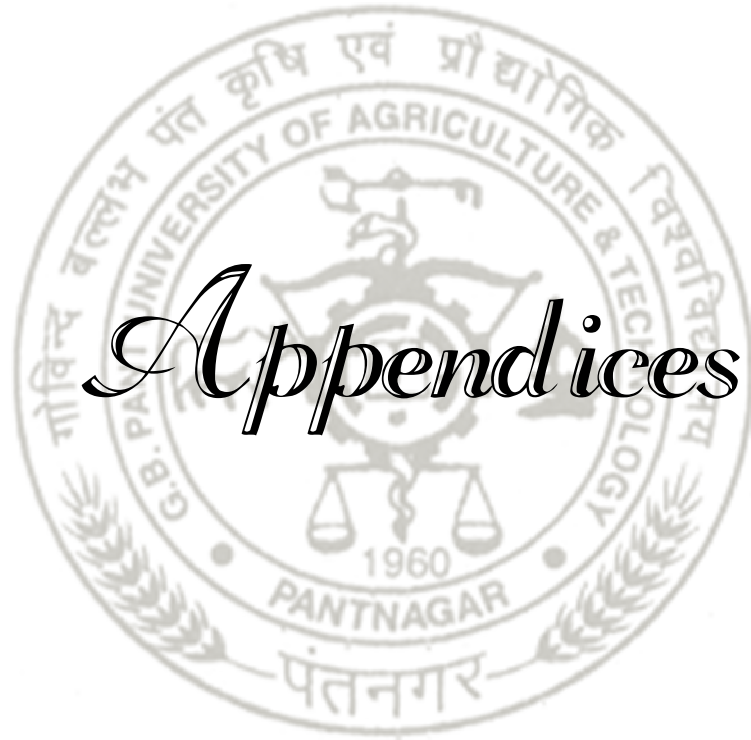
- Patil, S. R., Lande, G. K., Awasthi, N. S. and Barkhade, U. P. 2014.** Effect of different doses of newer insecticides against sucking pests of okra. *The Bioscan* 9(4): 1597-1600.
- Paul, S. and Konar, A. 2005.** Population dynamics of whitefly on potato planted on different dates. *Potato Journal*, 32: 3-4.
- Pawar, S. R. and Bharpoda, T. M. 2013.** Efficacy of botanicals and synthetic insecticides against aphid, *Uroleucon compositae* Theobald infesting safflower. *Pesticide Research Journal*, 25(1): 29-35.
- Pezzini, D. T. and Koch, R. L. 2015.** Compatibility of flonicamid and a formulated mixture of pyrethrins and azadirachtin with predators for soybean aphid (Hemiptera: Aphididae) management. *Biocontrol Science and Technology*, 25(9): 1024-1035.
- Preetha, G., Manoharan, T., Stanley, J. and Kuttalam, S. 2009.** Persistent toxicity of Imidacloprid 17.8 SL to aphid, *Aphis gossypii* Glover and leafhopper, *Amrasca biguttula biguttula* Ishida in Bhendi. *Pest management in horticultural ecosystems*, 15(2): 121-125.
- Preetha, G., Stanley, J and Manoharan, T. 2012.** Bioefficacy of imidacloprid 17.8 SL against cotton aphids and leafhoppers. *Indian Journal of Entomology*. 74(4): 336-342.
- Rahman, M. M., Latif, M. A., Islam, M. R. and Nuruddin, M. M. 2009.** Survey of arthropod biodiversity in the brinjal field. *Journal of Entomology*, 6(1): 28-34.
- Rai, A. B., Satpathy, S., Gandhi Gracy, R. and Swamy, T. M. S. 2009.** Some approaches in management of sucking pests on chilli with special reference to tarsonemid mite, *Polyphago tarsonemuslatus* Bank. *Vegetable Science*, 36(3): 297-303.
- Rashid, M. H., Khatun, M. J., Mahfuz, M. S., Dash, C. K. and Hussain, M. A. 2013.** Seasonal fluctuation of insect pests of brinjal at agricultural research station. *International Journal of Agricultural Resources*, 3(1): 4- 8.
- Ratanpara, H. C.; Shekh, A. M.; Patel, J. R. and Patel, N. M. 1994.** Effect of weather parameters on brinjal jassids, *A. biguttula biguttula* Ishida. *Gujarat Agriculture University Research Journal*, 19(2): 39-43.

- Ravi Kumar, V. 2014.** “Evaluation of certain cotton genotypes against sucking pests and their management with insecticides”. (Doctoral dissertation, ACHARYA NG RANGA AGRICULTURAL UNIVERSITY).
- Reddy, A. S., Venugopal Rao, N., Ankaiah, R., Rao, Y. N and Khasim, S. M. 1991.** Incidence of whitefly (*Bemisia tabaci*) in relation to leaf characters of upland cotton (*Gossypium hirsutum*). *Indian Journal of Agricultural Science*. 60(9): 619-624.
- Roditakis, E., Fytrou, N., Staurakaki, M., Vontas, J. and Tsagkarakou, A. 2014.** Activity of flonicamid on the sweet potato whitely *Bemisia tabaci* (Homoptera: Aleyrodidae) and its natural enemies. *Pest management science*, 70(10): 1460-1467.
- Rouhani, M., Samih, M. A., Izadi, H. and Mohammadi, E. 2013.** Toxicity of new insecticides against pomegranate aphid, *Aphis punicae*. *International Research Journal of Applied and Basic Sciences*, 4(3): 496-501.
- Saha, Cork, A., Kamal, N. Q., Alam, S. N., J. S. and Talekar, N. S. 2001.** Pheromone and their applications to insect pest control. *Bangladesh journal of Entomology*, 13(2): 1-13.
- Saljoqi, A. 2009.** Population dynamics of *Myzus persicae* (Sulzer) and its associated natural enemies in spring potato crop, Peshawar, Pakistan. *Journal of Agriculture*, 25(3): 451-456.
- Saljoqi, A. U. R. and Van Emden, H. F. 2003.** Effects of two potential pest management components, intercropping and yellow sticky plastic sheet traps in two differential resistant potato cultivars for the management of *Myzus persicae* (Sulzer). *Asian Journal of Plant Sciences*, 2(12): 925-931.
- Santharam, G., Kumar, K., Chandrasekaran, S. and Kuttalam, S. 2003.** Bioefficacy and residues of imidacloprid in chilies used against chili thrips. *Madras Agricultural Journal*, 90(7): 395-399.
- Sarkar, A., Konar, A., Hazra, S. and Choudhuri, S. 2008.** Incidence and chemical control on Mustard in new alluvial zone of west Bengal. *Journal of Entomology Research*, 31(1): 41-43.

- Sarwar, M. 2013.** Studies on Incidence of Insect Pests (Aphids) and Their Natural Enemies in Canola, *Brassica napus* L. (Brassicaceae) Crop Ecosystem. *International Journal of Scientific Research in Environmental Science*, 1(5): 78-84.
- Sathe, T. V. and Margaj, G. S. 2001.** Cotton pests and bio control agent. *Daya Publication House, Delhi*. pp. 25-26.
- Sathyan, T., Murugesan, N., Elanchezhyan, K., Raj, A. S. and Ravi, G. 2016.** Efficacy of Synthetic Insecticides against sucking insect pests in cotton, *Gossypium hirsutum* L. *International Journal of Entomological Research*, 1: 16-21.
- Satpathy S., Kumar A., Shivalingaswamy, T. M. and Rai, M. 2007.** Evaluation of new molecules for diamond backmoth (*Plutella xylostella* L.) management in cabbage. *Indian Journal of Horticulture*, 64(2): 175-177.
- Satpathy S., Kumar A., Singh A. K. and Pandey P. K. 2005.** Chlorfenapyr: A new molecule for diamondback moth (*Plutella xylostella* L.) management in cabbage. *Annul Plant Protection science*. 13(1): 88-90.
- Satpathy, S., Rai, A. B., Shivalingaswamy, T. M., Kodandram, M. H. and Kumar, A. 2010.** Effect of novel bio rational molecules - polymer combination as seed treatments on jassid population and seed vigor in okra. National Conference on Production of quality seeds planting material, health management in horticultural crops”, held on March 11-14, 2010 at New Delhi, pp. 84
- Scarpellini, J. R. and Andrade, D. J. 2011.** Efeito de inseticidas sobre a joaninha *Cycloneda sanguinea* L. (Coleoptera, Coccinellidae) e sobre o pulgão *Aphis gossypii* Glover (Hemiptera, Aphididae) em algodoeiro. *Arquivos do Instituto Biológico*, 78(3): 393-399.
- Sesha, M. 2007.** Impact of *Bt* cotton on the incidence and management of Bollworm complex. Thesis submitted to Acharya N.G. Ranga Agricultural University, Rajendranagar, and Hyderabad.
- Sharaf F. H., El-basyouni S. A. and Hamid A. M., 2003.** Insecticidal efficiency of some chemical compounds on the whitefly, *Bemisia tabaci* (Gennad.) infesting cotton plants and its associated natural enemies. *Journal of Agricultural Science* 28(2): 1419–1423

- Sharaf, F. H., El-Basyouni, S. A. and Hamid, A. M. 2002.** Insecticidal efficiency of some chemical compounds on the whitefly, *Bemisia tabaci* (Gennad.) infesting cotton plant and its associated natural enemies. *Journal of Agricultural Sciences*, 28(1): 1419-1423
- Sharma, G. N. and Sharma, P. D. 1997.** Population dynamics of cotton jassid (*Amrasca biguttula biguttula*) and whitefly (*Bemisia tabaci*) on cotton and okra in relation to the physical factor of environment in Haryana. *Annul. Bio. Ludhiana*, 13(1): 179-183.
- Shinde, S. T., Shetgar, S. S., and Badgujar, A. G. 2011.** Bio-efficacy of different insecticides against major pest of okra. *Journal of Entomological Research*, 35(2): 133-137.
- Shivalingaswamy, T. M., Satpathy, S., Singh, B. and Kumar, A. 2002.** Predator-prey interaction between jassid (*Amrasca biguttula biguttula*, Ishida) and a staphylinid in okra. *Vegetable Science*, 29(2): 167-169.
- SHM. 2018.** Official website of state horticulture mission. *Govt. of Uttarakhand*
- Shukla, A. 2006.** Seasonal activity of thrips, *Scirtothrips dorsalis* on chilli crop. *Indian Journall of Tropical Biodiversity*.14(2): 171-174.
- Shukla, K. R. 2014.** Seasonal incidence of sucking pest and their natural enemies on potato. *Journal of Environmental Sciences*, 54(3): 11-13.
- Shukla, N. 2014.** Seasonal incidence and relation to weather parameters of aphid and their natural enemies on okra. *International Journal of Science and Research* 4(3): 1-3.
- Shukla, R. P. 1989.** Population fluctuation of *Leucinodes orbonalis* Guen. and *Amrasca biguttula biguttula* Ishida on brinjal in relation to abiotic factors in Meghalaya. *Indian Journal of Agricultural Research*, 59: 260-64.
- Silva, F. S., Lobo, S. E. P. D., Lima, D. C. B., Birto, J. M. and Costa-Neta, B. M. 2015.** The Influence of weather and lunar phases on the flight activity of Rove beetles, *Paederus dermatitis* (Coleoptera: Staphylinidae). *Environmental entomology*, 44(3): 874

- Singh, S. S., Tiwari, H. C. and Singh, V. P. 2003.** Management of leaf curl aphid, *Brachycaudus helichrysi* (Kalt) in peach orchard using insecticides. *Annals of Plant Protection Sciences* 11(1): 35-37.
- Sose, S. 2005.** Morphological characters of *Leptinotarsa decemlineata* (say) and dynamics of the population in 2002-2003.
- Srivastava, A. S., Katiyar, S. S. L., Awasthi, B. K., Srivastava, K. M. and Nigam, P.M. 1971.** Field assessment of aphid population on potato crop. *Zeitschrift fur angewandte Entomologie*, 69.1(4): 44-48.
- Tank, B. D. and Korat, D. M. 2007.** Influence of Weather Parameters on Population of *Cheilomenes sexmaculata*. *Karnataka Journal of Agricultural Science*, 20(3): 642-643.
- Tomar, S., Sharma, S. and Malik, K. 2017.** Diafenthiuron (a novel insecticide) for management of whitefly, *Bemisia tabaci*. *Indian Journal of Scientific Research*, 120-123.
- Usman, A., Elemo, K. A., Bala, A. and Umar, A. (2012).** Effect of weed interference and nitrogen on yields of a maize/rice intercrop. *International Journal of Pest Management*, 47(4): 241-246.
- Wahla, M. A., Tufail, M. and Iqbal, P. 1997.** The comparative effectiveness of different doses of Confidor 200SL and Tamaron 600SL against cotton thrips, *Thrips tabaci* Lind. on FH-582, cotton. *Pakistan Entomologist*, 19(1-2): 8-10.
- Way, M. J. 1968.** Intra-specific mechanism with special reference to aphid population. In. T.R.E. Southwood (Ed). *Insect Abundance*. Pp.18-36.
- Williamson, S. 1998.** Understanding natural enemies; a review of training and information in the practical use of biological control. *Biocontrol News and Information*, 19 (4): 117-126.
- Wrzodak, R. and Woszczyk, K. 2011.** The possibility of protection of white cabbage against aphids using insecticide containing flonicamid. *Progress in Plant Protection*. 51(1): 252-256.



The author was born on 10 Oct 1993 at place Kimmi, Naugaon, Uttarakashi (Uttarakhand). He passed her High School examination in 2009 from Saraswati Vidya Mandir Naugaon Uttarakashi, Intermediate examination in 2011 from A.S.S.D.D.L.T. Intermediate College Uttarakashi with 1st division and Diploma in Pharmacy in 2013 from Govt. Polytechnic Uttarakashi. He has completed her B.Sc. degree from, Veer Chandra Singh Garhwali Uttarakhand University Horticulture & Forestry Bharsar in 2017. He joined the G. B. Pant University of Agriculture and Technology, Pantnagar for the degree of M.Sc. Ag. With major in Entomology in the year 2017.

Address for correspondence:

*Anil rana
Vill –Kimmi , P.O.-Naugaon
Distt.-Uttarakashi
(Uttrakhand)
Pin code-249171
☎ : 8126503283
E-mail: anilrana13014@gmail.com
Website : WwW.HortiAgri.Com*

ABSTRACT

Name : Anil Rana **I.D. No.** : 52538
Sem.& year : 1st semester, 2017-18 **Degree** : M.Sc. (Ag.)
Major : Entomology **Deptt.** : Entomology
Thesis Title : **Management of insect pests of potato with some novel insecticides**
Advisor : **Dr. R.M. Srivastava**

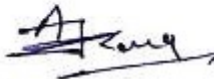
Present study entitled "Management of insect pests of potato with some novel insecticides" was conducted at Vegetable Research Center, G.B. Pant University of Agriculture and Technology, Pantnagar in *Tarai* region of Uttarakhand during the year 2018-19. During the course of study, the major insect pests observed attacking potato variety Kufri Surya were green peach aphid (*Myzus persicae* Sulzer), thrips (*Thrips palmi* Kamy), leaf hopper, (*Empoasca devastans*) and whitefly (*Bemisia tabaci* Genn.). The peak activity of green peach aphid (12.13 per plant) was observed during fourth week of November. In case of leaf hopper, peak activity was recorded 5.43 per plant, during third week of January, whereas, peak activity of whitefly (15.46) was recorded during second week of December and peak activity of thrips (18.80) was recorded during third week of December.

Correlation studies were worked out between the population of predators and that of sucking pests. There was a positive correlation between aphid and ladybird beetle, thrips and lady bird beetle, leaf hopper and lady bird beetle with "r" value of 0.94, 0.86 and 0.79, respectively at 5 percent level of significance.

Comparative studies of two chemicals were conducted for their efficacy against major insect pests of potato, of these, flonicamid 50 WG @ 3gm /10 lits with repeat 15 days after 1st spray was found as the more effective than imidacloprid insecticides against aphids (*Myzus persicae*), whitefly (*Bemesia tabaci*), jassid (*Empoasca devastans*) and thrips (*Thrips palmi*) followed by other treatments. After perusing the yield data it was observed that potato tuber yield was maximum (41 t/ha) in flonicamid 50 WG @ 3g / 10 lits + repeat at 15 days with 34.41 percent increase over control.

While studying the Bioefficacy of various insecticide it has been observed that seed treatment with imidacloprid (200 SL) @ 0.04% followed by foliar Spray of imidacloprid @60 g a.i. /ha at 85% emergence and repeated second spray with thiamethoxam 25 WG @ 100g a.i. /ha was most effective against potato insect pest like aphid (*Myzus persicae*), whitefly (*Bemesia tabaci*), jassid (*Empoasca devastans*) and thrips (*Thrips palmi*) followed by diafenthiuron as compared to other treatments castor oil could not manage the insect pests.


(R. M. Srivastava)
Advisor


(Anil Rana)
Author

सारांश

नाम	: अनिल राणा	परिचायक सं०	: 52538
सत्र एवं प्रवेश का वर्ष	: प्रथम 2017-18	उपाधि	: स्नातकोत्तर (कृषि)
मुख्य	: कीट विज्ञान	विभाग	: कीट विज्ञान
शोधग्रन्थ	: "नवीनतम कीटनाशकों के द्वारा आलू के कीटों का प्रबन्धन"		
सलाहकार	: डा० आर० एम० श्रीवास्तव		

उपरोक्त वर्णित शोध ग्रंथ शीर्षक "नवीनतम कीटनाशकों के द्वारा आलू के कीटों का प्रबन्धन" के अनुरूप वैज्ञानिक अध्ययन गोबिन्द बल्लभ पन्त कृषि एवं प्रौद्योगिकी विश्वविद्यालय पन्तनगर, के सब्जी अनुसंधान केन्द्र में अक्टूबर 2018 से मार्च 2019 के दौरान किया गया, इस शोध के दौरान जिसमें आलू की फसल में लगने वाले प्रमुख रस चूसक कीटों माहू (चैपा), थ्रिप्स, फुदका, सफेद मक्खी व उनके प्राकृतिक शत्रु (लेडी बर्ड बीटल, मकड़ी व स्टेफाइलीनीड बीटल) कीटों की आबादी का फसल में अध्ययन एवं उनकी आबादी को प्रभावित करने वाले कारको जैसे तापमान, आर्द्रता, वायुवेग, प्रकाशकाल समय के साथ तुलनात्मक आकलन किया गया। आलू की फसल में इन चूसक कीटों का आने का अन्तराल व उनकी अधिकतम संख्या को देखा गया जिसमें माहू की अधिकतम आबादी नवम्बर के सप्ताह में 12.13 प्रति पौधा व फुदका की अधिकतम आबादी 5.43 प्रति पौधा जनवरी के तीसरे सप्ताह तथा सफेद मक्खी की अधिकतम सक्रियता 15.46 प्रति पौधा जनवरी के तीसरे सप्ताह और थ्रिप्स की अधिकतम सक्रियता 18.80 प्रति पौधा दिसम्बर के तीसरे सप्ताह में पाई गई।

विभिन्न जैव नियंत्रक कारक कीटों का हानिकारक कीटों के साथ सहसम्बन्ध तुलनात्मक अध्ययन किया गया। लेडी बर्ड बीटल का माहू, थ्रिप्स व फुदके के साथ सहसम्बन्ध निकाला गया जो कि धनात्मक रहा। इनके बीच धनात्मक सहसम्बन्ध का मान 0.94, 0.86 व 0.79 रहा।

दो प्रमुख कीटनाशकों की क्षमता का तुलनात्मक अध्ययन से यह निष्कर्ष निकाला की फ्लोनिकामिड 50 डब्ल्यू० जी० अधिक प्रभावशाली तरीके से आलू के रस चूसक कीटों को नियंत्रित करता है। यह रसायन किसानों के मध्य प्रचलित रसायन इमिडाक्लोप्रिड से अधिक प्रभावशाली पाया गया।

विभिन्न कीटनाशकों का बुआई के समय व फसल पर छिड़काव के अध्ययन से यह निष्कर्ष निकाला की इमिडाक्लोप्रिड 200 एस० एल० 0.04 प्रतिशत का आलू की बुआई के दौरान कटों को पूर्ण रूप से भिगोकर बुआई करने से 85 प्रतिशत पौधे के निकलने के पश्चात पुनः इसी रसायन का छिड़काव 60 ग्राम ऐ० आई० प्रति हेक्टेयर की दर से करने से व दस दिनों के उपरान्त थियामेथाक्सम 25 डब्ल्यू० जी० 100 ग्राम ऐ० आई० प्रति हेक्टेयर दर से करने से आलू की फसल की पैदावार उपरोक्त रसायनों से सर्वाधिक पाई गयी। इसके बाद सर्वाधिक प्रभावशाली रसायन डाइफेनथियूरॉन पाया गया आलू के कीट नियंत्रण में अरण्डी के तेल का उपयोग प्रभावशाली नहीं रहा।


(आर० एम० श्रीवास्तव)
सलाहकार


(अनिल राणा)
शोधकर्ता